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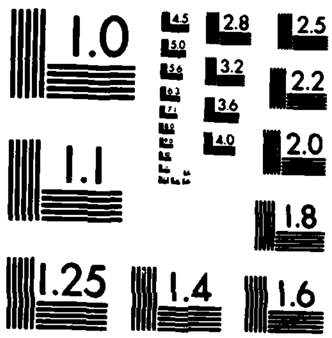
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PSI TR-416

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AUTOTHERMAL REFORMER FUEL CELL POWER PLANTS

FINAL TECHNICAL REPORT

by

David P. Bloomfield

28 February 1984

Prepared for

U. S. ARMY MOBILITY EQUIPMENT
RESEARCH AND DEVELOPMENT COMMAND
Fort Belvoir, VA 22060

Under Contract No. DAAK70-83-C-0041

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report summarizes the work performed under contract DAAK70-83-C-0041. A total of six systems models were developed and analyzed. The first of these considered a hydrocarbon fueled, ATR based power plant. The next three systems examined three condensing approaches to a neat methanol fuel cell power plant. Finally, two non-condensing approaches to neat methanol operation were investigated. One of these, configuration G041G, was selected for extensive parametric analysis. The system used

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an Autothermal reforming fuel processor in conjunction with an air cooled fuel cell stack.

As part of the program a systems model of the Energy Research Corp. fuel cell was developed. In addition, the existing ATR model in the PSI/ S3E library was updated to permit the analysis of methanol fuel.

Each of the systems developed is completely described in a separate chapter.

All computer codes developed under the contract have been supplied in BASIC source code suitable for implementation on an IBM/PC computer. All codes function in the PSI/S3E environment except for the parametric analysis of GO41G which also uses the LOTUS 1 2 3 environment.

CONTENTS

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CHAPTER 1

SUMMARY

CHAPTER 1
SUMMARY

OBJECTIVES

The objective of the program was to determine the chrarcteristics of a neat methanol fuel cell power plant for an Army application. Computerized power plant models were developed to select optimum fuel cell and fuel processing technologies. With several systems modeled, we determined the set of operating and design conditions which would yield the optimum power plant design for the Army program. Along with the Army objectives of neat methanol operation, a power level of 5 kW, it was required that the power plant be operable over a wide range of ambient conditions. In addition it was desireable that the resulting power plant be relatively small and light.

Another objective of the program was to develop and deliver computer codes to the Belvoir R&D Center to assist their personnel in fuel cell power plant systems analysis.

INTRODUCTION

This report summarizes all work which was performed by PSI/Systems for the Belvoir R & D Center under contract DAAK70-83-C-0041. During the course of the contract we delivered the PSI/S3E computer code which can be used by the Army in future systems analysis of fuel cell power plants.

During the course of the contract a total of six systems models were developed. This includes the formulation of the flow schematic and the development of Main Programs to support these analyses. In addition a total of five new graphics displays of the systems give the analyst an on-line picture of how the analysis is progressing. These graphics displays have considerably enhanced the utility of the PSI/S3E code in systems analysis. Supporting diagnostics codes were also written for the graphics displays. The last case to be developed included the synthesis of an additional set of codes to provide high speed parametric analysis of configuration G041G. This configuration includes an ATR with cathode recycle for the reforming of neat methanol fuel. The effort required the development of five separate codes and four separate data structures. During the analysis of this configuration a total of 576 cases were evaluated. The data structures developed permit the use of LOTUS 1-2-3 spreadsheet for the final optimization of the design and operating conditions.

As part of the program we also developed a new fuel cell performance module, PAFCY, which more accurately modes the performance of Energy Research Corp. cell stacks. Many of the configurations studied use methanol in autothermal reformers (ATR's). For this purpose, the existing PSI/S3E ATR module was updated to use methanol as a fuel.

Of the six configurations formulated and evaluated, the first looked at a hydrocarbon fueled ATR based power plant. Next we examined three condensing approaches to neat methanol fuel cell power plants. Finally we developed two non-condensing fuel cell power plant configurations which operate on neat methanol.

This report first presents our findings with regard to the G041G2 configuration which is judged to be the most promising and which was most extensively investigated. Next, we have presented a brief overview of each of the methanol systems analyzed. Each of the systems developed is more completely described in a separate chapter. Each chapter is organized to give a system description along with the results and condluseions. All applicable computer codes have been included in the appendices to this report. In particular, the modeling approach followed during the course of evaluating configuration G041G2 is presented in appendix 2.

This chapter concludes with a discussion of the results, conclusions and recommendations with regard to each of the methanol systems studied.

BACKGROUND

The development of power plants utilizing methanol-water premix was influenced by a 1978 analysis performed by United Technologies Corporation (UTC) for the Army (ref 1). It was then concluded that, "The premix power plant utilizing an air cooled stack has the greatest potential for meeting...requirements." At that time the choices were either process air cooled or liquid cooled stacks. Process air cooled stacks were compact but did not allow water recovery. Liquid cooled stacks would allow water recovery but imposed an unacceptable weight penalty for small power plants.

Energy Research Corporation (ERC) is the prime contractor for the development of 3 and 5 kW fuel cell power plants for the Army. During the course of the ERC program, the Army supported design and development of Separate Air Cooled (SAC) stacks. This design was subsequently incorporated into 3 and 5 kW power plants because of better startup features and availability of clean warm air form potential space heating applications. Of great importance to utilizing neat methanol, SAC stacks allow water recovery.

STATEMENT OF THE PROBLEM

Before getting into the details of the modeling effort we will start with a brief review of the problem and the technologies considered for use in the power plant. First, the fuel cell to be employed is the phosphoric acid type, however the nature of the stack cooling approach to be employed was left open. The fuel processor must process methanol into hydrogen for the fuel cell. No type was specified and we were free to chose from conventional methanol reforming processes or partial oxidation or

autothermal reforming. In order to meet the Army requirements of size and weight, it is desireable to minimize not only the stack and fuel processor but the number and size of auxiliary components as well. These components constitute the balance of the plant and are required to maintain all components in thermal equilibrium over the range of operating conditions.

In addition to component selection and configuration, the power plant system design requires the determination of how the system will react to variations in design and operating conditions. With these reactions quantified we are then in a position to select the optimum conditions.

CONSTRAINTS

While, at first glance it appears that we can start with a clean slate in synthesizing a system. In actuality, the problem is highly constrained. Water is produced by the electrochemical reaction of hydrogen and oxygen in the fuel cell. The product water is principally evolved at the cathode especially at the high current density associated with design point, or rated load operation. Since no other water is available for fuel processing, it is this product water which must be recovered if steam reforming is to be considered. This constraint means that we can select one of three system options:

1. Separate the water from the fuel cell effluent streams and deliver the water to the fuel processor.
2. Use a fuel processor which does not require water to produce hydrogen from methanol.
3. Configure a system which does not require the separation of water from the fuel cell effluent streams.

In addition to water management, it is desireable that the power plant operate at a reasonable efficiency; 20% to 30%. While this efficiency is low enough so that waste heat recovery is not critical, it is high enough to demand that reasonable cell voltages are obtainable. In addition to the efficiency requirement, the power plant size and weight are a major concern to the Army. This demands that relatively high performance be attained in both the fuel processor and the fuel cell. In the course of our studies we did investigate partial oxidation fuel processing. We found that partial oxidation would not only be inefficient but the high quantities of carbon monoxide would degrade the fuel cell anode performance.

The fact that the power plant must operate over a wide range of ambient conditions augers against the use of condensing systems to provide water to the fuel processor. Any system utilizing condensing water separation would be prone to freezing in cold ambient conditions. In the course of our analyses we did investigate two condensing approaches to determine the relative size of these systems.

APPROACH FOLLOWED IN THE MODELING PROCESS

Having defined the nature of the problem including its constraints, we will now briefly review the general approach we followed in developing and analyzing the systems. A more complete discussion of this process is given in Appendix 2. In general we follow the procedure:

1. DEVELOP A TRIAL CONFIGURATION
2. FLOWSHEET MODEL SYNTHESIS
3. PRELIMINARY DESIGN POINT ANALYSIS
4. OPTIMIZATION

On the following pages we have shown the flowsheet and associated node array corresponding to five configurations analyzed in the course of this program. These data are representative cases which are obtained from the corresponding computer models which were delivered as part of this report. Each case is more completely described in a separate chapter of this report. The chapters include a walk through of the system flowsheet, the results of our analyses and the conclusions and recommendations appropriate to each case.

In this section we will simply present the flowsheets and node array data for each of the cases. The thermodynamic data found in Tables 1.1 through 1.5 are keyed to the flowsheet node numbers in Fig. 1.1 through 1.5. Table 1.1 and Fig 1.1 show a hydrocarbon reforming fuel cell power plant which uses condensing water recovery. This configuration is designated G041C and is completely described in Chapter 2. In Fig 1.2 and Table 1.2 we show a liquid cooled methanol fueled, fuel cell power plant which employs a liquid cell stack coolant. This coolant happens to be a mixture of water and methanol. The configuration uses a condensing type of water recovery and is designated G041D and is described in Chapter 3 of this report. In Fig 1.3 and Table 1.3 we show an air cooled, methanol fueled, fuel cell power plant. This configuration is designated G041E and is described in Chapter 4 of this report.

In Fig. 1.4 and table 1.4 we show configuration G041F which employs a catalytic partial oxidation fuel processor. The process uses a non-condensing method of water recovery. Because the partial oxidation process produces a high concentration of carbon monoxide, we have used an adiabatic water recovery unit to humidify the shift converter inlet. Unfortunately, this is still insufficient to reduce the carbon monoxide to acceptable levels. The G041F process is dealt with in more detail in Chapter 5.

Configuration G041G is described by Fig 1.5 and table 1.5. This process, employing an autothermal reformer in conjunction with a cathode recycle loop is the most promising of the systems studied. The process is completely described in chapter 6. In addition Appendix 2 details the programming operations performed to obtain parametric data on this process.

RESULTS

In the following paragraphs we will describe the results obtained in the systems modeling of configuration G, the autothermal reforming power plant using an air cooled fuel cell stack. This system gave the most promising results. The system schematic is shown in Fig. 1.6. For a complete discussion of the system configuration the reader should consult Chapter 6.

A parametric study was conducted with configuration G041G. The study involved running a compiled version of the steady state design point analysis and summarizing the results in a data file. This data was then sorted to determine the set of design parameters and operating conditions which would yield a power plant with the minimum volume and which would also have an efficiency better than 20%.

PARMETER	VALUE
O2/C	0.15
UH	0.65
VO	0.58 volts
T(L2)	70-125 deg F
TATR	800 deg F

In the sorting process we identified those cases having the highest overall efficiency. This efficiency is 27.1%. Because the stack areas of these systems are very large, due to the high cell voltage, we examined the case of powerplants having efficiencies above 20% and having the smallest stack areas. These cases all occur at cell voltages of 0.58, the lowest cell voltage used in the study. One must conclude that low cell voltage, and concomittantly low cell stack area is required to obtain minimum volume.

It is also interesting to note that most of the cases of both low volume and high efficiency occured at the lowest values of ATR exit temperature. In fact of the ten cases examined for lowest volume no ATR temperature other than 800 deg F was obtained.

CONCLUSIONS

While the results of the study appear to be encouraging, several questions arise in conjucntion with the feasiblity of operating a real power plant at the conditions shown. We first address the question of cathode air utilization. In all optimum cases, the air utilization is above 84%. The PSI/S3E fuel cell model is a steady state model of the power plant. While it calculates the effect of oxygen partial pressure on cell performance, it does not address the problem of flow maldistribution between cells. Certainly, at high utilizations this is an important consideration.

In the autothermal reforming case, the oxygen utilization is determined by the oxygen to carbon ratio required in the autothermal reformer. Specifically, the oxygen to carbon ratio will determine the ATR exit temperature. It is not an independent parameter. While we could bleed air off at the cathode exit, this would reduce the water available to the autothermal reformer. The result would be more CO production and lower efficiency in the fuel processor. Another alternative would be to pressurize the process. Generally this has not been considered attractive in the past because commercially available turbochargers do not have the low flow capacity required by low power power plants.

Since the power plant is air cooled, we may consider turbocharging of both the cooling and process air. This increase in turbocharger flow rate makes pressurized operation feasible. Moreover, with commercially available turbochargers, a compressor exit temperature of about 250 deg F would be attained. This would permit the elimination of the recycle air preheat system shown in configuration G.

Next, the use of an autothermal reformer could result in the production of methane if conventional nickel catalysts were used. An autothermal reformer catalyst which suppresses methane formation is required. While it has not been tested under autothermal reforming conditions, Engelhard has developed a catalyst which shows the required reforming properties at the temperatures of interest.

Another important question is; assuming that the system will function properly at the rated power point, it is not known how the system will react at reduced power levels. A concern is that while water evolution occurs at the cathode under high load conditions, this becomes less true at reduced power levels. Under these conditions, the anode and cathode water vapor concentrations tend to equilibrate. The result of this equilibration will be a reduction of the steam delivered to the autothermal reformer and a reduction in its efficiency. At the present time we have not analyzed the extent of this effect.

RECOMMENDATIONS

It is recommended that configuration G041G be re-examined in a turbocharged configuration. A preliminary analysis indicates that this would yield a promising power plant configuration. In addition, it is recommended that a preliminary evaluation of configuration G041F be made at elevated pressures. The dilution of electrolyte which occurs at high pressure might significantly improve the shift converter inlet humidification.

We also recommend that a study be performed to adequately determine the weights, volumes and costs associated with Army power plants. In all cases our systems volumes are only approximate. This portion of the recommended program will consititute the development of a specification for Army fuel cell power plants.

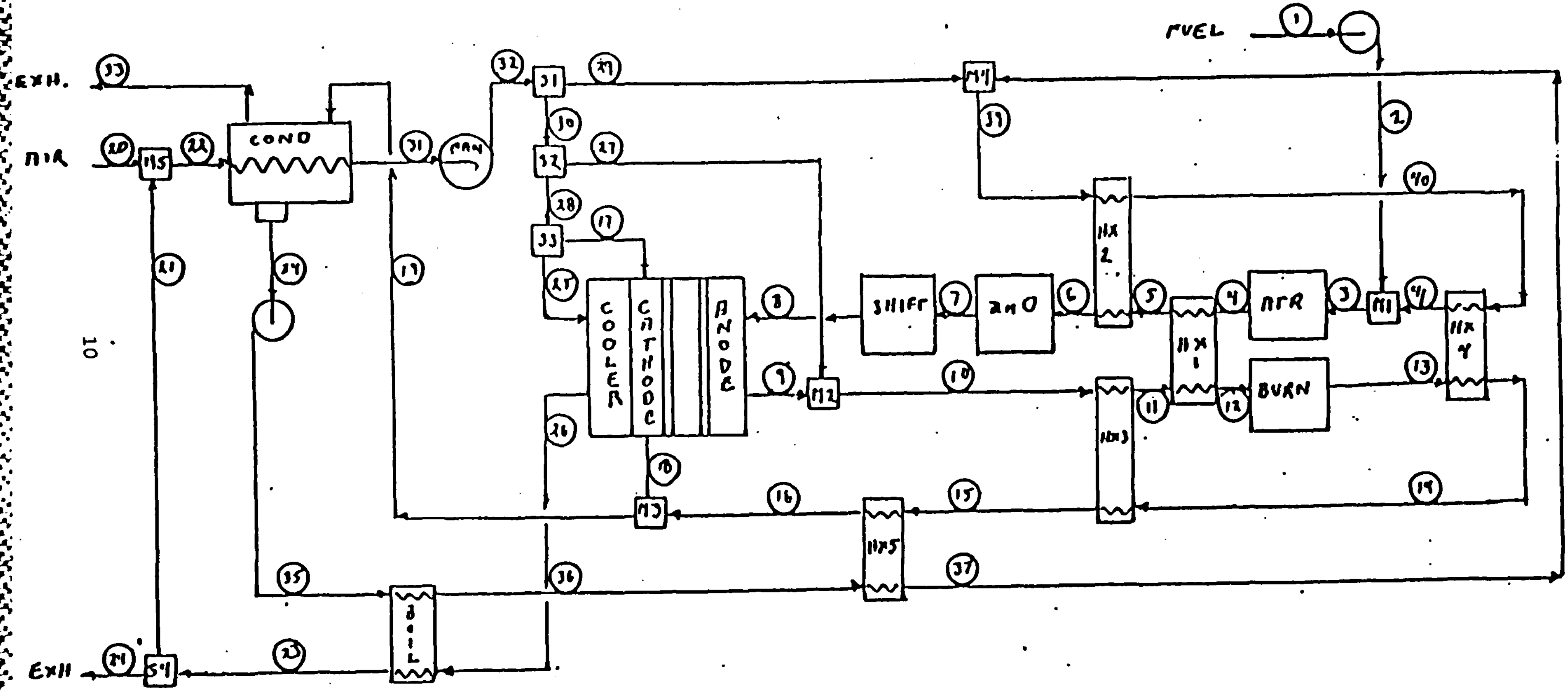

Fig. 1.1 Configuration G041.C ATR/fuel cell power plant conventional water recovery.

TABLE 1.1 CONFIGURATION GO41C PSI/S3E NODE ARRAY

	MOLAR FLOW RATES - lb mole/hr									Press	Temp	Enthalpy	
NODE	H2	H2O	CH4	CO	CO2	O2	N2	FUEL	TOT	ATM	Deg-F	BTU/hr	NODE
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	1
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	2
3	0.0000	0.6480	0.0000	0.0000	0.0000	0.0648	0.2419	0.0144	0.9691	1.0000	1400	-4.9009E+04	3
4	0.3676	0.4532	0.0000	0.1076	0.1084	0.0000	0.2419	0.0000	1.2787	1.0000	1605	-4.9009E+04	4
5	0.3676	0.4532	0.0000	0.1076	0.1084	0.0000	0.2419	0.0000	1.2787	1.0000	1247	-5.3090E+04	5
6	0.3676	0.4532	0.0000	0.1076	0.1084	0.0000	0.2419	0.0000	1.2787	1.0000	891	-5.6971E+04	6
7	0.3676	0.4532	0.0000	0.1076	0.1084	0.0000	0.2419	0.0000	1.2787	1.0000	400	-6.2026E+04	7
8	0.4684	0.3524	0.0000	0.0068	0.2092	0.0000	0.2419	0.0000	1.2787	1.0000	569	-6.2026E+04	8
9	0.1405	0.3524	0.0000	0.0068	0.2092	0.0000	0.2419	0.0000	0.9508	1.0000	375	-6.5889E+04	9
10	0.1405	0.3524	0.0000	0.0068	0.2092	0.0924	0.5867	0.0000	1.3879	1.0000	340	-6.3731E+04	10
11	0.1405	0.3524	0.0000	0.0068	0.2092	0.0924	0.5867	0.0000	1.3879	1.0000	900	-5.7347E+04	11
12	0.1405	0.3524	0.0000	0.0068	0.2092	0.0924	0.5867	0.0000	1.3879	1.0000	1235	-5.3264E+04	12
13	0.0000	0.4929	0.0000	0.0000	0.2160	0.0187	0.5867	0.0000	1.3143	1.0000	2441	-5.3264E+04	13
14	0.0000	0.4929	0.0000	0.0000	0.2160	0.0187	0.5867	0.0000	1.3143	1.0000	1870	-6.0966E+04	14
15	0.0000	0.4929	0.0000	0.0000	0.2160	0.0187	0.5867	0.0000	1.3143	1.0000	1156	-7.0012E+04	15
16	0.0000	0.4929	0.0000	0.0000	0.2160	0.0187	0.5867	0.0000	1.3143	1.0000	943	-7.2549E+04	16
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.3213	1.2122	0.0000	1.5334	1.0000	375	8.9226E+03	17
18	0.0000	0.3213	0.0000	0.0000	0.0000	0.1606	1.2122	0.0000	1.6940	1.0000	375	-2.2891E+04	18
19	0.0000	0.8142	0.0000	0.0000	0.2160	0.1793	1.7989	0.0000	3.0083	1.0000	645	-9.5440E+04	19
20	0.0000	0.0000	0.0000	0.0000	0.0000	5.4815	20.4639	0.0000	25.9454	1.0000	70	9.5525E+04	20
21	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	21
22	0.0000	0.0000	0.0000	0.0000	0.0000	0.4784	1.8050	0.0000	2.2835	1.0000	70	8.4072E+03	22
23	0.0000	0.0000	0.0000	0.0000	0.0000	5.2032	19.4237	0.0000	24.6269	1.0000	300	1.3024E+05	23
24	0.0000	0.0000	0.0000	0.0000	0.0000	5.0000	18.6650	0.0000	0.0000	0.0000	0	0.0000E+00	24
25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	25
26	0.0000	0.0000	0.0000	0.0000	0.0000	5.2032	19.4237	0.0000	24.6269	1.0000	375	1.4330E+05	26
27	0.0000	0.0000	0.0000	0.0000	0.0000	0.0924	0.3448	0.0000	0.4372	1.0000	250	2.1576E+03	27
28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	28
29	0.0000	0.0000	0.0000	0.0000	0.0000	0.0648	0.2419	0.0000	0.3067	1.0000	250	1.5137E+03	29
30	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	30

TABLE 1.1 (CONTINUED) CONFIGURATION GO41C PSI NODE ARRAY

	MOLAR FLOW RATES - lb mole/hr									Press	Temp	Enthalpy	
NODE	H2	H2O	CH4	CO	CO2	O2	N2	FUEL	TOT	ATM	Deg-F	BTU/hr	NODE
31	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	31
32	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	32
33	0.0000	0.7507	0.0000	0.0000	0.2160	0.1793	1.7989	0.0000	2.9449	1.0000	150	-1.0066E+05	33
34	0.0000	0.0635	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0635	1.0000	150	-7.3744E+03	34
35	0.0000	0.6480	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6480	1.0000	140	-7.5410E+04	35
36	0.0000	0.6480	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6480	1.0000	360	-6.2353E+04	36
37	0.0000	0.6480	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6480	1.0000	813	-5.9817E+04	37
38	0.0000	0.6480	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6480	1.0000	350	-6.2407E+04	38
39	0.0000	0.6480	0.0000	0.0000	0.0000	0.0648	0.2419	0.0000	0.9547	1.0000	321	-6.0894E+04	39
40	0.0000	0.6480	0.0000	0.0000	0.0000	0.0648	0.2419	0.0000	0.9547	1.0000	818	-5.7013E+04	40
41	0.0000	0.6480	0.0000	0.0000	0.0000	0.0648	0.2419	0.0000	0.9547	1.0000	1702	-4.9310E+04	41
42	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	42
43	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	43
44	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	44
45	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	45
46	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	46
47	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	47
48	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	48
49	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	49
50	0.0000	0.8142	0.0000	0.0000	0.2160	0.1793	1.7989	0.0000	3.0083	1.0000	152	-1.0683E+05	50
51	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	51
52	0.0000	0.0000	0.0000	0.0000	0.0000	5.2032	19.4237	0.0000	24.6269	1.0000	370	1.4251E+05	52
53	0.0000	0.0000	0.0000	0.0000	0.0000	5.2032	19.4237	0.0000	24.6269	1.0000	306	1.3119E+05	53
54	0.0000	0.6480	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6480	1.0000	212	-7.4467E+04	54
55	0.0000	0.6480	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6480	1.0000	212	-6.3143E+04	55
56	0.0000	0.6480	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6480	1.0000	360	-6.2353E+04	56
57	0.4684	0.3524	0.0000	0.0068	0.2092	0.0000	0.2419	0.0000	1.2787	1.0000	569	-6.2026E+04	57
58	0.1405	0.3524	0.0000	0.0068	0.2092	0.0924	0.5867	0.0000	1.3879	1.0000	1120	-5.4686E+04	58

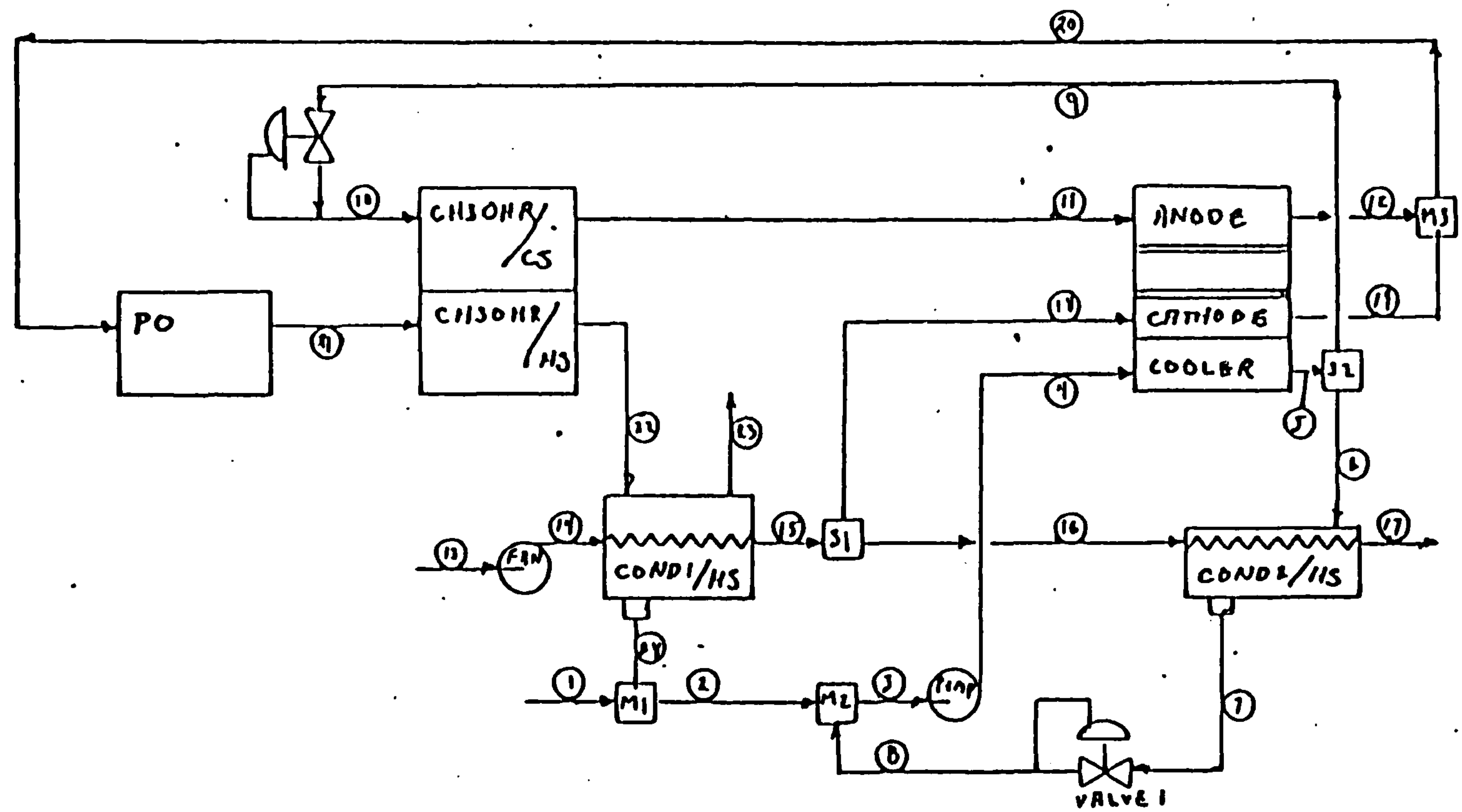

Fig. 1.2 Configuration GO41.D liquid cooled CH3OH fuel cell power plant.

TABLE 1.2 CONFIGURATION GO41D PSI/S3E NODE ARRAY

NODE	MOLAR FLOW RATES - lb mole/hr H2	H2O	CH4	CO	CO2	O2	N2	FUEL	TOT	Press ATM	Temp Deg-F	Enthalpy BTU/hr	NODE
1	0.0000	0.2898	0.0000	0.0000	0.0000	0.0000	0.0000	0.2229	0.5127	1.000	70	-4.5741E+04	1
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.000	0	0.0000E+00	2
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.000	0	0.0000E+00	3
4	0.0000	2.4207	0.0000	0.0000	0.0000	0.0000	0.0000	1.8621	4.2828	14.956	345	6.7010E+03	4
5	0.0000	2.4207	0.0000	0.0000	0.0000	0.0000	0.0000	1.8621	4.2828	14.956	345	6.7010E+03	5
6	0.0000	2.1309	0.0000	0.0000	0.0000	0.0000	0.0000	1.6392	3.7701	14.956	345	5.1051E+04	6
7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	14.956	0	0.0000E+00	7
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.000	0	0.0000E+00	8
9	0.0000	0.2898	0.0000	0.0000	0.0000	0.0000	0.0000	0.2229	0.5127	14.956	345	-4.4350E+04	9
10	0.0000	0.2898	0.0000	0.0000	0.0000	0.0000	0.0000	0.2229	0.5127	1.000	345	-4.4350E+04	10
11	0.6425	0.0887	0.0000	0.0196	0.2011	0.0000	0.0000	0.0022	0.9542	1.000	375	-3.8485E+04	11
12	0.1285	0.0887	0.0000	0.0196	0.2011	0.0000	0.0000	0.0022	0.4402	1.000	375	-4.1424E+04	12
13	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.000	0	0.0000E+00	13
14	0.0000	0.0000	0.0000	0.0000	0.0000	5.0000	18.8650	0.0000	23.8650	1.000	70	8.7866E+04	14
15	0.0000	0.0000	0.0000	0.0000	0.0000	5.0000	18.8650	0.0000	23.8650	1.000	180	1.0611E+05	15
16	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.000	0	0.0000E+00	16
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.000	0	0.0000E+00	17
18	0.0000	0.0000	0.0000	0.0000	0.0000	0.3341	1.2607	0.0000	1.5948	1.000	375	9.2795E+03	18
19	0.0000	0.5140	0.0000	0.0000	0.0000	0.0771	1.2607	0.0000	1.8518	1.000	375	-4.1622E+04	19
20	0.1285	0.6027	0.0000	0.0196	0.2011	0.0771	1.2607	0.0022	2.2919	1.000	375	-8.3045E+04	20
21	0.0000	0.7312	0.0000	0.0000	0.2207	0.0030	1.2607	0.0022	2.2179	1.000	1231	-8.3043E+04	21
22	0.0000	0.7312	0.0000	0.0000	0.2207	0.0030	1.2607	0.0022	2.2179	1.000	877	-8.9850E+04	22
23	0.0000	0.4404	0.0000	0.0000	0.2207	0.0030	1.2607	0.0022	1.9270	1.000	146	-7.4306E+04	23
24	0.0000	0.2908	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2908	1.000	146	-3.3815E+04	24
25	0.0000	0.0000	0.0000	0.0000	0.0000	0.3341	1.2607	0.0000	1.5948	1.000	70	5.8715E+03	25
26	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0	0.0000E+00	26
27	0.6425	0.0887	0.0000	0.0196	0.2011	0.0000	0.0000	0.0022	0.9542	1.000	500	-3.7543E+04	27
28	0.0000	0.5652	0.0000	0.0000	0.0000	0.0000	0.0000	0.4348	1.0000	14.956	345	-8.6495E+04	28
29	0.0000	0.7312	0.0000	0.0000	0.2207	0.0030	1.2607	0.0022	2.2179	1.000	161	-1.0255E+05	29

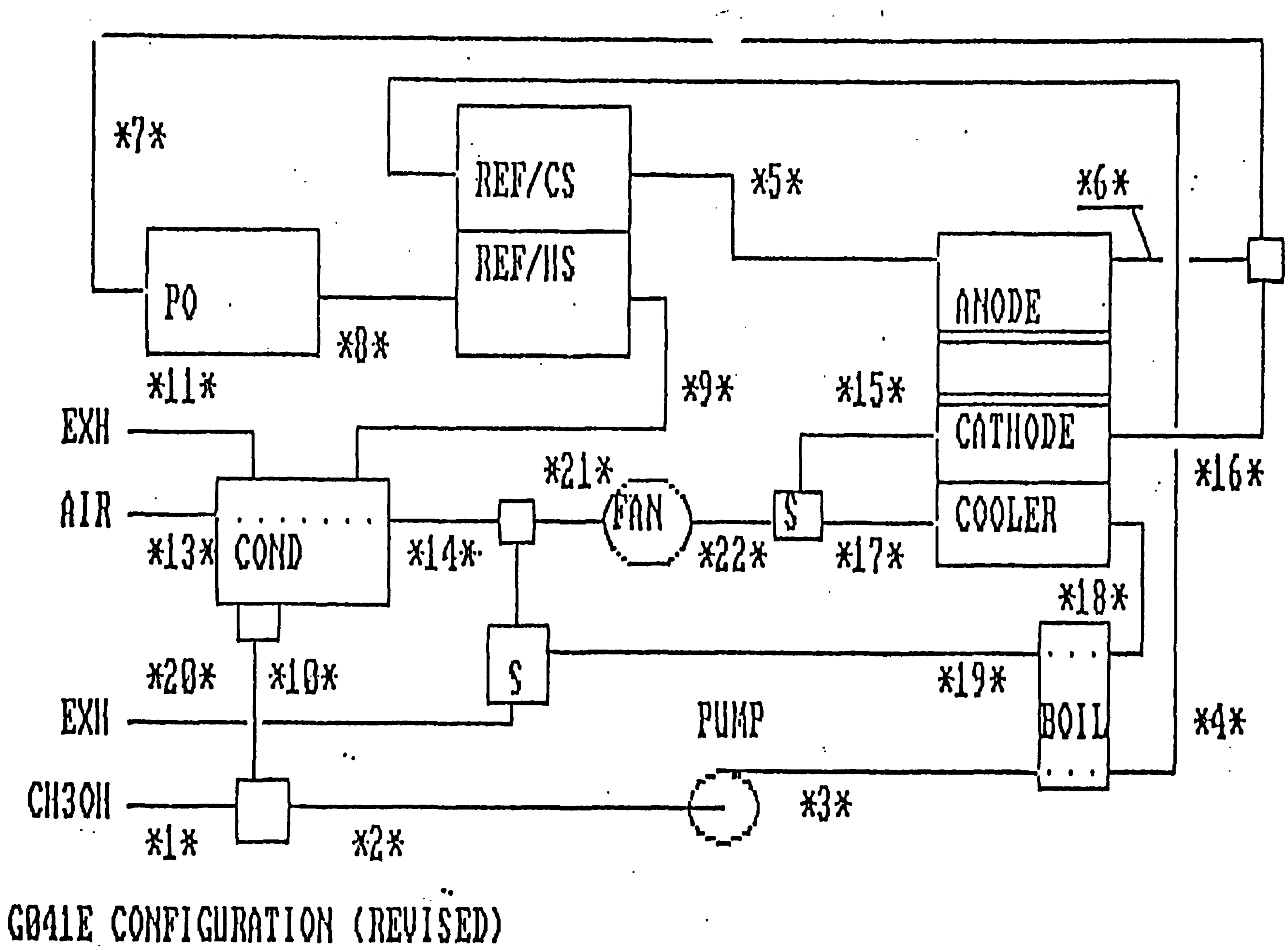

Fig. 1.3 Original GO41E configuration.

TABLE 1.3 CONFIGURATION GO41E PSI/S3E NODE ARRAY

NODE	H2	H20	CH4	CO	CO2	O2	N2	FUEL	TOT	Press ATM	Temp Deg-F	Enthalpy BTU/hr	NODE
	MOLAR FLOW RATES - lb mole/hr												
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2229	0.2229	1.000	70	-2.0855E+04	1
2	0.0000	0.2898	0.0000	0.0000	0.0000	0.0000	0.0000	0.2229	0.5127	1.000	70	-5.4973E+04	2
3	0.0000	0.2898	0.0000	0.0000	0.0000	0.0000	0.0000	0.2229	0.5127	1.000	70	-5.4973E+04	3
4	0.0000	0.2898	0.0000	0.0000	0.0000	0.0000	0.0000	0.2229	0.5127	1.000	320	-4.4485E+04	4
5	0.6425	0.0887	0.0000	0.0196	0.2011	0.0000	0.0000	0.0022	0.9542	1.000	375	-3.8485E+04	5
6	0.1285	0.0887	0.0000	0.0196	0.2011	0.0000	0.0000	0.0022	0.4402	1.000	375	-4.1424E+04	6
7	0.1285	0.6027	0.0000	0.0196	0.2011	0.0771	1.2607	0.0022	2.2919	1.000	375	-8.3045E+04	7
8	0.0000	0.7312	0.0000	0.0000	0.2207	0.0030	1.2607	0.0022	2.2179	1.000	1231	-8.3043E+04	8
9	0.0000	0.7312	0.0000	0.0000	0.2207	0.0030	1.2607	0.0022	2.2179	1.000	870	-8.9985E+04	9
10	0.0000	0.2898	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2898	1.000	146	-3.3693E+04	10
11	0.0000	0.4414	0.0000	0.0000	0.2207	0.0030	1.2607	0.0022	1.9281	1.000	146	-7.4407E+04	11
12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.000	0	0.0000E+00	12
13	0.0000	0.0000	0.0000	0.0000	0.0000	4.4193	16.6752	0.0000	21.0944	1.000	70	7.7665E+04	13
14	0.0000	0.0000	0.0000	0.0000	0.0000	4.4193	16.6752	0.0000	21.0944	1.000	193	9.5749E+04	14
15	0.0000	0.0000	0.0000	0.0000	0.0000	0.3341	1.2607	0.0000	1.5948	1.000	375	9.2795E+03	15
16	0.0000	0.5140	0.0000	0.0000	0.0000	0.0771	1.2607	0.0000	1.8518	1.000	375	-4.1622E+04	16
17	0.0000	0.0000	0.0000	0.0000	0.0000	6.7635	25.5207	0.0000	32.2842	1.000	250	1.5934E+05	17
18	0.0000	0.0000	0.0000	0.0000	0.0000	6.7635	25.5207	0.0000	32.2842	1.000	375	1.8785E+05	18
19	0.0000	0.0000	0.0000	0.0000	0.0000	6.7635	25.5207	0.0000	32.2842	1.000	329	1.7737E+05	19
20	0.0000	0.0000	0.0000	0.0000	0.0000	4.0852	15.4145	0.0000	19.4997	1.000	329	1.0713E+05	20
21	0.0000	0.0000	0.0000	0.0000	0.0000	7.0976	26.7813	0.0000	33.8790	1.000	251	1.6735E+05	21
22	0.0000	0.0000	0.0000	0.0000	0.0000	7.0976	26.7813	0.0000	33.8790	1.000	251	1.6735E+05	22
23	0.0000	0.0000	0.0000	0.0000	0.0000	2.6784	10.1062	0.0000	12.7846	1.000	329	7.0237E+04	23
24	0.0000	0.2898	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2898	1.000	146	-3.3693E+04	24
25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.000	0	0.0000E+00	25
26	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0	0.0000E+00	26
27	0.6425	0.0887	0.0000	0.0196	0.2011	0.0000	0.0000	0.0022	0.9542	1.000	500	-3.7543E+04	27
28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0	0.0000E+00	28
29	0.0000	0.7312	0.0000	0.0000	0.2207	0.0030	1.2607	0.0022	2.2179	1.000	161	-1.0255E+05	29
30	0.0000	0.0000	0.0000	0.0000	0.0000	4.4193	16.6752	0.0000	21.0944	1.000	108	8.3182E+04	30

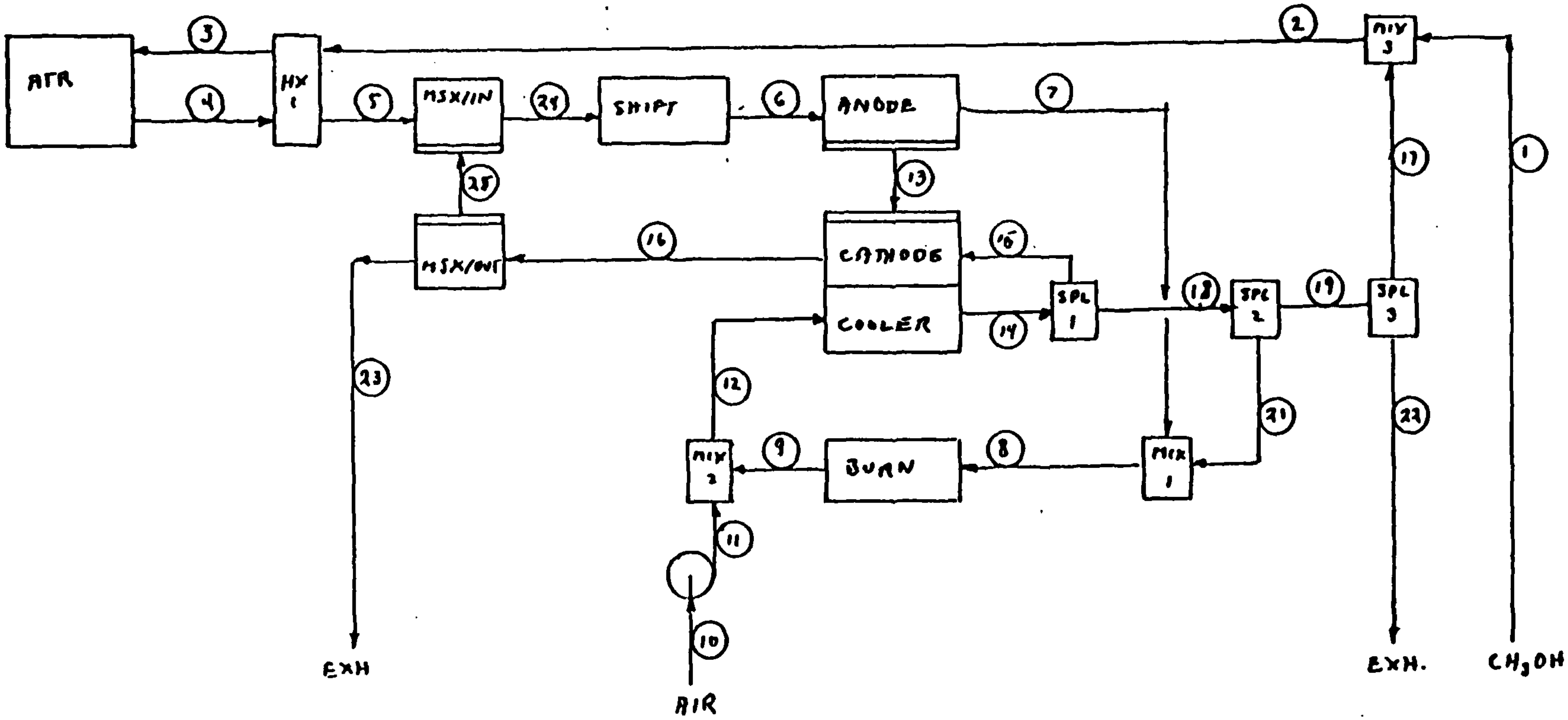

Fig. 1.4 Configuration GO41F.

TABLE 1.4 CONFIGURATION GO41F PSI/S3E NODE ARRAY

	MOLAR FLOW RATES - lb mole/hr									Press	Temp	Enthalpy	
NODE	H2	H2O	CH4	CO	CO2	O2	N2	FUEL	TOT	ATM	Deg-F	BTU/hr	NODE
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3962	0.2857	1.000	70	-3.7060E+04	1
2	0.0001	0.0072	0.0000	0.0001	0.0063	0.1188	0.4683	0.3962	0.8865	1.000	160	-3.5398E+04	2
3	0.0001	0.0072	0.0000	0.0001	0.0063	0.1188	0.4683	0.3962	0.8865	1.000	310	-2.7953E+04	3
4	0.6717	0.1279	0.0000	0.2793	0.1233	0.0000	0.4683	0.0000	1.6705	1.000	1142	-2.7953E+04	4
5	0.6717	0.1279	0.0000	0.2793	0.1233	0.0000	0.4683	0.0000	1.6705	1.000	567	-3.5395E+04	5
6	0.8566	0.0881	0.0000	0.0944	0.3082	0.0000	0.4683	0.0000	1.8156	1.000	602	-5.1726E+04	6
7	0.3427	0.0881	0.0000	0.0944	0.3082	0.0000	0.4683	0.0000	1.3017	1.000	375	-5.7855E+04	7
8	0.3429	0.1032	0.0000	0.0947	0.3213	0.2500	1.4533	0.0000	2.5655	1.000	370	-5.4360E+04	8
9	0.0000	0.4462	0.0000	0.0000	0.4160	0.0312	1.4533	0.0000	2.3467	1.000	2581	-5.4360E+04	9
10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.000	0	0.0000E+00	10
11	0.0000	0.0000	0.0000	0.0000	0.0000	7.2592	27.3908	0.0000	34.6500	1.000	70	1.2757E+05	11
12	0.0073	0.4389	0.0000	0.0080	0.3827	7.2592	28.6038	0.0000	36.7000	1.000	255	7.2813E+04	12
13	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.000	0	0.0000E+00	13
14	0.0073	0.4389	0.0000	0.0080	0.3827	7.2592	28.6038	0.0000	36.7000	1.000	365	1.0151E+05	14
15	0.0004	0.0254	0.0000	0.0005	0.0221	0.4193	1.6523	0.0000	2.1199	1.000	365	5.8637E+03	15
16	0.0004	0.5032	0.0000	0.0005	0.0221	0.1677	1.6523	0.0000	2.3462	1.000	375	-4.1380E+04	16
17	0.0001	0.0072	0.0000	0.0001	0.0063	0.1188	0.4683	0.0000	0.6009	1.000	365	1.6620E+03	17
18	0.0069	0.4136	0.0000	0.0075	0.3606	6.8399	26.9516	0.0000	34.5800	1.000	365	9.5648E+04	18
19	0.0066	0.3985	0.0000	0.0072	0.3475	6.5899	25.9665	0.0000	33.3162	1.000	365	9.2152E+04	19
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.000	0	0.0000E+00	20
21	0.0003	0.0151	0.0000	0.0003	0.0132	0.2500	0.9850	0.0000	1.2638	1.000	365	3.4957E+03	21
22	0.0065	0.3913	0.0000	0.0071	0.3412	6.4710	25.4982	0.0000	32.7153	1.000	365	9.0490E+04	22
23	0.0004	0.3580	0.0000	0.0005	0.0221	0.1677	1.6523	0.0000	2.2010	1.000	375	-2.7432E+04	23
24	0.6717	0.2730	0.0000	0.2793	0.1233	0.0000	0.4683	0.0000	1.8156	1.000	375	-5.1726E+04	24
25	0.0000	0.1451	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1451	1.000	375	-1.3948E+04	25

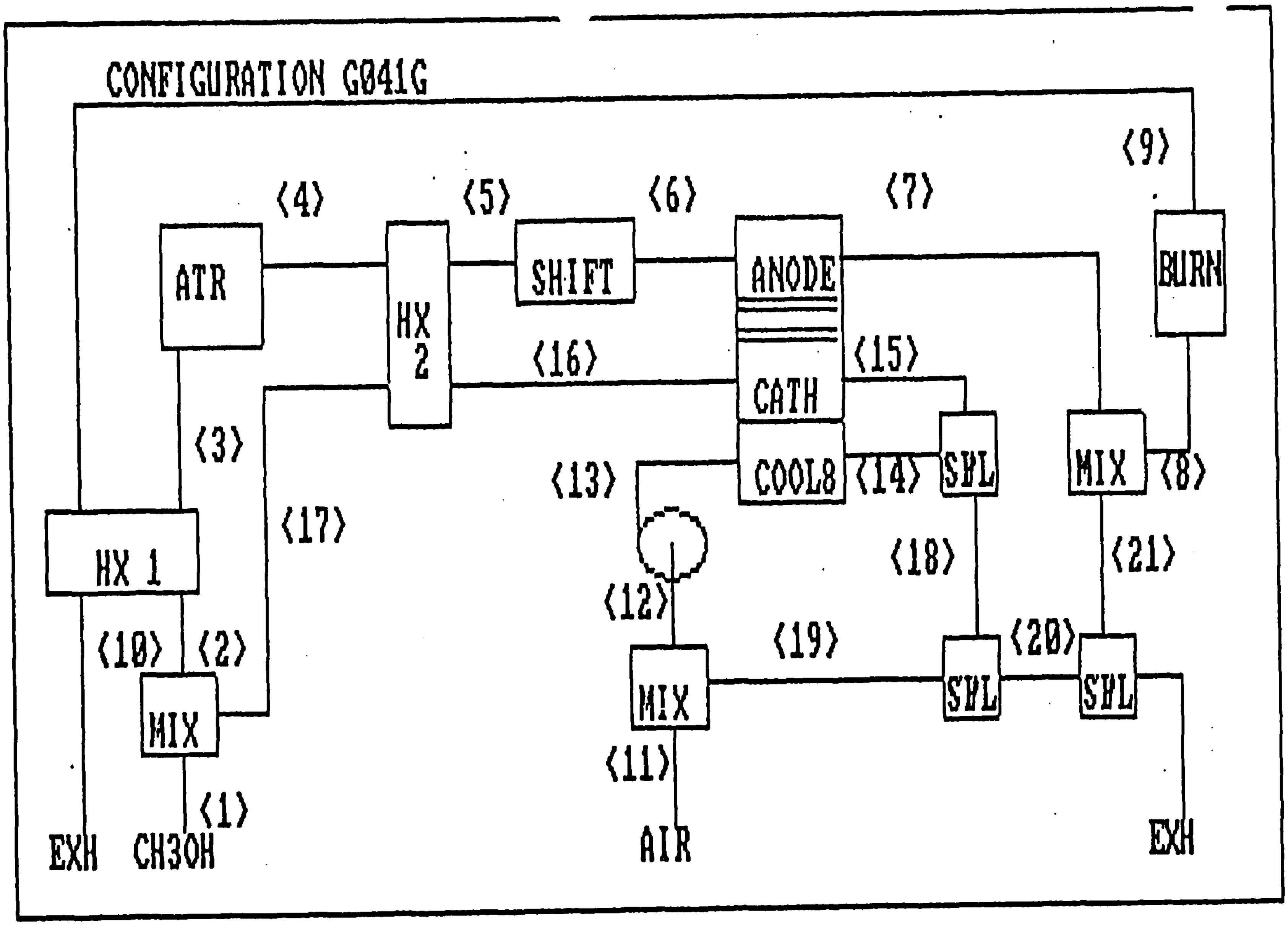

Fig. 1.5 Configuration G041G.

TABLE 1.5 CONFIGURATION GO41G PSI/S3E NODE ARRAY

	MOLAR FLOW RATES - lb mole/hr									Press	Temp	Enthalpy	
NODE	H2	H2O	CH4	CO	CO2	O2	N2	FUEL	TOT	ATM	Deg-F	BTU/hr	NODE
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3241	0.3241	1.000	70	-3.0315E+04	1
2	0.0000	0.4377	0.0000	0.0000	0.0000	0.0648	1.0703	0.3241	1.8969	1.000	279	-6.0747E+04	2
3	0.0000	0.4377	0.0000	0.0000	0.0000	0.0648	1.0703	0.3241	1.8969	1.000	557	-5.6189E+04	3
4	0.7727	0.3131	0.0000	0.0699	0.2542	0.0000	1.0703	0.0000	2.4802	1.000	800	-5.5567E+04	4
5	0.7727	0.3131	0.0000	0.0699	0.2542	0.0000	1.0703	0.0000	2.4802	1.000	400	-6.3240E+04	5
6	0.8334	0.2524	0.0000	0.0091	0.3149	0.0000	1.0703	0.0000	2.4802	1.000	455	-6.3240E+04	6
7	0.3334	0.2524	0.0000	0.0091	0.3149	0.0000	1.0703	0.0000	1.9801	1.000	375	-6.7615E+04	7
8	0.3126	0.3044	0.0000	0.0612	0.2770	0.2429	1.9869	0.0000	3.1850	1.000	375	-6.2080E+04	8
9	0.0000	0.6170	0.0000	0.0000	0.3382	0.0561	1.9869	0.0000	2.9981	1.000	1935	-6.2080E+04	9
10	0.0000	0.6170	0.0000	0.0000	0.3382	0.0561	1.9869	0.0000	2.9981	1.000	1772	-6.6633E+04	10
11	0.0000	0.0000	0.0000	0.0000	0.0000	2.7719	10.4593	0.0000	13.2312	1.000	70	4.8714E+04	11
12	0.0000	0.0000	0.0000	0.0000	0.0000	6.7635	25.5207	0.0000	32.2842	1.000	250	1.5934E+05	12
13	0.0000	0.0000	0.0000	0.0000	0.0000	6.7635	25.5207	0.0000	32.2842	1.000	250	1.5934E+05	13
14	0.0000	0.0000	0.0000	0.0000	0.0000	6.7635	25.5207	0.0000	32.2842	1.000	375	1.8785E+05	14
15	0.0000	0.0000	0.0000	0.0000	0.0000	0.2837	1.0703	0.0000	1.3540	1.000	375	7.8783E+03	15
16	0.0000	0.4377	0.0000	0.0000	0.0000	0.0648	1.0703	0.0000	1.5728	1.000	375	-3.5465E+04	16
17	0.0000	0.4377	0.0000	0.0000	0.0000	0.0648	1.0703	0.0000	1.5728	1.000	796	-3.0432E+04	17
18	0.0000	0.0000	0.0000	0.0000	0.0000	6.4799	24.4504	0.0000	30.9303	1.000	375	1.7997E+05	18
19	0.0000	0.0000	0.0000	0.0000	0.0000	3.9916	15.0614	0.0000	19.0530	1.000	375	1.1086E+05	19
20	0.0000	0.0000	0.0000	0.0000	0.0000	2.4883	9.3890	0.0000	11.8773	1.000	375	6.9111E+04	20
21	0.0000	0.0000	0.0000	0.0000	0.0000	0.2429	0.9166	0.0000	1.1595	1.000	375	6.7471E+03	21
22	0.0000	0.0000	0.0000	0.0000	0.0000	2.2454	8.4724	0.0000	10.7177	1.000	375	6.2363E+04	22

TABLE 1.6 SYSTEM DATA BLOCK

```
PARAMETRIC STUDY PARAMETERS

ATR O2/C=  .2
HYDROGEN UTILIZATION  .6
CELL VOLTS = .58
AIR INLET TEMP= 70
ATR EXIT TEMP, DEFAULT = 800
POWER (KW)
         NET= 5              GROSS= 7.25   PARASITE= .8
         CELL VOLTAGE= .58   CURRENT DENSITY= 155.1461   ASF
         FUEL CELL AREA= 80.56923  SQFT
         NUMBER OF CELLS @ 1.4 FT2= 58
         STACK VOLTS= 33.64
         STACK CURRENT= 217.2045 ;AMP

         CELL TEMPERATURE= 375 DEG F
UTILIZATIONS
         HYDROGEN= .6        AIR(STACK)= .7715096
         BURNER ENRICHMENT= 1.2

ATR FUEL PROCESSOR OUTPUT
WATER TO FUEL RATIO= 1.350621             O2/FUEL RATIO= .2
EFFICIENCY
         OVERALL= .1811391
         FUEL CELL= .4629999              MECHANICAL= .8620689
         INVERTER= .8        FUEL PROCESSOR= .5672823

 X DATA NTU
         HX-1= .1939107      HX-2= 9.255756
HEAT EXCHANGER AREA
                   HX 1 AREA= 3.170811  FT2          HX 2 AREA= 110.8781  FT2

QBAL DATA
         Q( 5 )=-2640.383
SECANT DATA
K( 1 )= 71    K( 2 )= 45    K( 3 )= 15    K( 4 )= 0     K( 5 )= 0
K( 6 )= 34    K( 7 )= 3     K( 8 )= 52    K( 9 )= 10    K( 10 )= 9    K( 11 )=
 13
```

TABLE 1.7

604162.WKS

THIS FILE IS FOR USE IN CONJUCTION WITH 604162.PRN FILSORT

COMMON PARAMETERS				***********************************
PNET	5.000 KW	EFFICIENCY		LOWEST OVERALL VOLUME
PGROSS	7.250 KW	MECH	0.862	
PARASITE	0.800 KW	INV	0.800	TOP 10 UNITS
				***********************************
TCELL	375.000 DEGF			
BURN ENR	1.200			

CASE	INDEPENDENT VARIABLES O2/C	UH	CELL VOLTS	AMBIENT TEMP	TATR	CURRENT DENSITY ASF	STACK AREA FT2	NUMBER CELLS	STACK VOLTS	STACK AMP	OXYGEN UTIL	H2O/C
203	0.150	0.650	0.580	105	800	142.176	87.919	63	36.540	199.047	0.855	1.763
207	0.150	0.650	0.580	125	800	142.176	87.919	63	36.540	199.047	0.855	1.763
199	0.150	0.650	0.580	90	800	142.176	87.919	63	36.540	199.047	0.855	1.763
195	0.150	0.650	0.580	70	800	142.176	87.919	63	36.540	199.047	0.855	1.763
267	0.150	0.700	0.580	125	800	138.534	90.231	64	37.120	193.947	0.864	1.900
264	0.150	0.700	0.580	105	800	138.534	90.231	64	37.120	193.947	0.864	1.900
261	0.150	0.700	0.580	90	800	138.534	90.231	64	37.120	193.947	0.864	1.900
258	0.150	0.700	0.580	70	800	138.534	90.231	64	37.120	193.947	0.864	1.900
307	0.100	0.600	0.580	70	800	139.172	89.817	64	37.120	194.841	0.894	1.684
311	0.100	0.600	0.580	90	800	139.172	89.817	64	37.120	194.841	0.894	1.684

CASE	EFFICIENCY OVERALL	STACK	FUEL PROC	HX AREA HX1	HX AREA HX2	FLOW RATES ACFM(NODE) ACFM4	ACFM9	ACFM11	ACFM12	Q(5) BTU/HR
203	0.225	0.463	0.704	0.623	6.900	33.970	65.235	100.779	273.549	2306.977
207	0.225	0.463	0.704	0.623	6.900	33.970	65.235	112.694	273.549	2306.977
199	0.225	0.463	0.704	0.623	6.900	33.970	65.235	92.940	273.549	2306.977
195	0.225	0.463	0.704	0.623	6.900	33.970	65.235	83.688	273.549	2306.977
267	0.242	0.463	0.758	0.739	6.757	32.986	55.915	112.694	273.549	2162.992
264	0.242	0.463	0.758	0.739	6.757	32.986	55.915	100.779	273.549	2162.992
261	0.242	0.463	0.758	0.739	6.757	32.986	55.915	92.940	273.549	2162.992
258	0.242	0.463	0.758	0.739	6.757	32.986	55.915	83.688	273.549	2162.992
307	0.208	0.463	0.650	0.917	6.485	35.033	78.095	83.688	273.549	2536.270
311	0.208	0.463	0.650	0.917	6.485	35.033	78.095	92.940	273.549	2536.270

STACK VOL FT3	REF VOL FT3	HX VOL FT3	INV VOL FT3	TOTAL VOL FT3
13.643	4.076	1.159	6.334	25.211
13.643	4.076	1.159	6.334	25.211
13.643	4.076	1.159	6.334	25.211
13.643	4.076	1.159	6.334	25.211
14.001	3.958	1.154	6.171	25.286
14.001	3.958	1.154	6.171	25.286
14.001	3.958	1.154	6.171	25.286
14.001	3.958	1.154	6.171	25.286
13.937	4.204	1.140	6.200	25.481
13.937	4.204	1.140	6.200	25.481

TABLE 1.8

604162.WKS
THIS FILE IS FOR USE IN CONJUCTION WITH 604162.PRN FILSORT

COMMON PARAMETERS				************************************
PNET	5.000 KW	EFFICIENCY		HIGHEST OVERALL EFFICIENCY
PGROSS	7.250 KW	MECH-	0.862	TOP 10 UNITS
PARASITE	0.800 KW	INV	0.800	
				************************************

TCELL 375.000 DEGF
BURN ENR 1.200

CASE	INDEPENDENT VARIABLES O2/C	UH	CELL VOLTS	AMBIENT TEMP	TATR	CURRENT DENSITY ASF	STACK AREA FT2	NUMBER CELLS	STACK VOLTS	STACK AMP	OXYGEN UTIL	H2O/C
294	0.150	0.700	0.650	70	800	52.248	213.478	152	98.800	73.148	0.864	1.900
295	0.150	0.700	0.650	90	1200	50.226	222.072	159	103.350	70.317	0.863	1.893
299	0.150	0.700	0.650	105	1000	51.195	217.870	156	101.400	71.673	0.863	1.897
298	0.150	0.700	0.650	105	1200	50.226	222.072	159	103.350	70.317	0.863	1.893
303	0.150	0.700	0.650	125	800	52.248	213.478	152	98.800	73.148	0.864	1.900
297	0.150	0.700	0.650	90	800	52.248	213.478	152	98.800	73.148	0.864	1.900
301	0.150	0.700	0.650	125	1200	50.226	222.072	159	103.350	70.317	0.863	1.893
292	0.150	0.700	0.650	70	1200	50.226	222.072	159	103.350	70.317	0.863	1.893
296	0.150	0.700	0.650	90	1000	51.195	217.870	156	101.400	71.673	0.863	1.897
300	0.150	0.700	0.650	105	800	52.248	213.478	152	98.800	73.148	0.864	1.900
302	0.150	0.700	0.650	125	1000	51.195	217.870	156	101.400	71.673	0.863	1.897

CASE	EFFICIENCY OVERALL	STACK	FUEL PROC	HX AREA HX1	HX AREA HX2	FLOW RATES ACFM(NODE) ACFM4	ACFM9	ACFM11	ACFM12	Q(5) BTU/HR
294	0.271	0.519	0.758	0.660	6.027	29.434	49.893	66.905	218.690	1930.274
295	0.271	0.519	0.758	1.893	6.055	38.700	52.925	74.302	218.690	4099.203
299	0.271	0.519	0.758	1.054	6.065	34.075	52.044	80.569	218.690	3011.399
298	0.271	0.519	0.758	1.893	6.055	38.700	52.925	80.569	218.690	4099.203
303	0.271	0.519	0.758	0.660	6.027	29.434	49.893	90.094	218.690	1930.274
297	0.271	0.519	0.758	0.660	6.027	29.434	49.893	74.302	218.690	1930.274
301	0.271	0.519	0.758	1.893	6.055	38.700	52.925	90.094	218.690	4099.203
292	0.271	0.519	0.758	1.893	6.055	38.700	52.925	66.905	218.690	4099.203
296	0.271	0.519	0.758	1.054	6.065	34.075	52.044	74.302	218.690	3011.399
300	0.271	0.519	0.758	0.660	6.027	29.434	49.893	80.569	218.690	1930.274
302	0.271	0.519	0.758	1.054	6.065	34.075	52.044	90.094	218.690	3011.399

TABLE 1.9

G04162.WKS
THIS FILE IS FOR USE IN CONJUCTION WITH G04162.PRN FILSORT

COMMON PARAMETERS					###################################
PNET	5.000 KW	EFFICIENCY			SMALLEST STACK AREA
PGROSS	7.250 KW	MECH	0.862		UNITS OVER 20% EFFICIENT
PARASITE	0.800 KW	INV	0.800		TOP 10 UNITS
					###################################

TCELL 375.000 DEGF
BURN ENR 1.200

CASE	INDEPENDENT VARIABLES O2/C	UH	CELL VOLTS	AMBIENT TEMP	TATR	CURRENT DENSITY ASF	STACK AREA FT2	NUMBER CELLS	STACK VOLTS	STACK AMP	OXYGEN UTIL	H2O/C
105	0.200	0.700	0.580	105	800	148.219	84.335	60	34.800	207.506	0.797	1.571
108	0.200	0.700	0.580	125	800	148.219	84.335	60	34.800	207.506	0.797	1.571
102	0.200	0.700	0.580	90	800	148.219	84.335	60	34.800	207.506	0.797	1.571
99	0.200	0.700	0.580	70	800	148.219	84.335	60	34.800	207.506	0.797	1.571
98	0.200	0.700	0.580	70	1000	145.902	85.674	61	35.380	204.263	0.798	1.576
104	0.200	0.700	0.580	105	1000	145.902	85.674	61	35.380	204.263	0.798	1.576
107	0.200	0.700	0.580	125	1000	145.902	85.674	61	35.380	204.263	0.798	1.576
101	0.200	0.700	0.580	90	1000	145.902	85.674	61	35.380	204.263	0.798	1.576
97	0.200	0.700	0.580	70	1200	143.797	86.928	62	35.960	201.316	0.798	1.581
100	0.200	0.700	0.580	90	1200	143.797	86.928	62	35.960	201.316	0.798	1.581

CASE	EFFICIENCY OVERALL	STACK	FUEL PROC	HX AREA HX1	HX AREA HX2	FLOW RATES ACFM(NODE) ACFM4	ACFM9	ACFM11	ACFM12	Q(5) BTU/HR
105	0.210	0.463	0.658	0.416	11.051	34.803	63.473	100.779	273.549	2262.317
108	0.210	0.463	0.658	0.416	11.051	34.803	63.473	112.694	273.549	2262.317
102	0.210	0.463	0.658	0.416	11.051	34.803	63.473	92.940	273.549	2262.317
99	0.210	0.463	0.658	0.416	11.051	34.803	63.473	83.688	273.549	2262.317
98	0.211	0.463	0.662	0.659	11.710	40.185	67.550	83.688	273.549	3482.008
104	0.211	0.463	0.662	0.659	11.710	40.185	67.550	100.779	273.549	3482.008
107	0.211	0.463	0.662	0.659	11.710	40.185	67.550	112.694	273.549	3482.008
101	0.211	0.463	0.662	0.659	11.710	40.185	67.550	92.940	273.549	3482.008
97	0.212	0.463	0.665	0.991	11.404	45.531	71.108	83.688	273.549	4710.567
100	0.212	0.463	0.665	0.991	11.404	45.531	71.108	92.940	273.549	4710.567

CHAPTER 2

CONFIGURATION GO41C
HYDROCARBON FUELED POWER PLANT

CHAPTER 2
CONFIGURATION G041C
HYDROCARBON FUELED POWER PLANT

INTRODUCTION

The first task to be addressed under this contract was the development of a hydrocarbon fueled fuel cell power plant. The system configured used an ATR based fuel processor. The power plant employed a conventional water recovery approach and used an air cooled cell stack. The configuration is shown in figure 1 of this report. Both a SYSM Module and a main program were developed as part of the program. All codes developed under this task are listed in Appendix 2 of this report. In this chapter we will give a description of the system which is illustrated in Fig 2.1. We will also give a summary of the results obtained along with conclusions and recommendations.

SYSTEM DESCRIPTION

We start our description of the system with a brief walk through of the species flows. As shown in Fig 2.1, air enters the system at node 20 and is preheated in the water recovery condenser. The air proceeds through three flow splitters. The first of these sends air to the ATR, the second sends air to a burner and the third divides the remaining air between the cell coolers and the cathode.

The cathode exhaust is mixed with burner exhaust ensuring that all water produced within the system is fed to the water recovery condenser. The liquid water recovered at node 34 proceeds to a boiler. The water is boiled using effluent from the stack cooling air. The stack cooling air, after passing through the boiler is exhausted. Note that provision is made to recycle some boiler air effluent to the condenser coldside inlet. This precludes freezing of liquid in the condenser.

The steam from the boiler proceeds to a superheater (HX-5) and then to a mixer (M4) where it is mixed with inlet air. The resultant air/steam mixture is preheated in HX-2 and HX-4 prior to being mixed with fuel in M1. Note the arrangement of heat exchangers HX-1 through HX-4. This relationship has been developed to optimize the transfer the energy from the anode exhaust to the fuel reforming section.

Once mixed with fuel, the air/steam/fuel stream at node 3 is sent directly to the ATR. The ATR effluent is cooled in HX-1 and HX-2 prior to being desulfurized and shifted. The shift converter effluent is sent to the anode. The anode effluent at node 9 is mixed with air from node 27 prior to being heated in HX-3 and HX-1. This mixture is then burned and the effluent cooled in HX-4 and HX-3. Again the heat exchange is optimized to return the maximum amount of heat to the fuel processor section. After passing through the fuel processor set of heat exchangers, the

remaining sensible heat in the burner exhaust is used to superheat steam, which also is used in the fuel processor. The results of the analysis performed on this system are given in Table 2.1. This table is an array of nodes (or stream locations) corresponding to the thermodynamic conditions which are found at the nodes shown in Fig 2.1.

RESULTS

Our findings indicate that the temperatures in the fuel processor are approximately correct. We experienced some problems with the modeling of the boiler. It appears that the heat available is sufficient to completely boil the water required by the ATR. We used a water to fuel carbon ratio of about 3 and the fuel is NO. 2. The O2/C ratio is about 0.3. Generally it is important to recover the waste heat from the fuel cell stack as steam to the fuel processor. If this is not done severe efficiency penalties will result. Since the power plant efficiency is very low (about 25%) this penalty may not be severe. In addition a great deal of waste heat at high temperature is available at node 16 (see Fig 1).

At first glance, the power plant seems to have an inordinate number of heat exchangers. This is done so that we get an accurate picture of how the heat should flow. In practice, the heat exchangers numbered 1-4 in the fuel processor might be incorporated into a single unit along with the ATR and the Burner. Likewise, the three splitters shown in Fig 1 (S1 -S3) might be housed in a single manifold.

Additional concerns with the present design evolve around pressure drops through the system. Note that the cathode air is mixed with burner exhaust in mixer M3. This is done to deliver the maximum concentration of water vapor to the condenser for recovery. However the short path from the fan through the cathode (nodes 32/30/28/17/18) compared with the long path of air from the fan to mixer M3 through the fuel processor (nodes 32/29/39/40/41/3/4/5/6/7/8/9/10/11/12/13/14/15/16) might dictate the use of an orifice at the cathode air exhaust. This in turn might result in excessive fan power consumption.

CONCLUSIONS ON THE HYDROCARBON/ATR POWER PLANT

1. The amount of water generated in the system is equal to the one half the hydrogen which enters the system as fuel hydrogen. The system property which controls the feasibilty of water recovery is the amount of air which enters the system in excess of the stoichiometric quantity.

2. In a conventionally configured water recovery system operating in conjunction with an ATR/Fuel Cell power plant, the sources of diluent air are:

Cell oxygen utilization
Burner enrichment ratio
ATR O_2/C ratio

Because of the requirement for full water recovery, these parameters must be minimized. Depending on the fuel, carbon formation may be a problem in the fuel processor. At low total pressures, the cell oxygen utilization may also be a problem.

3. Work on this configuration was terminated due to the desire on the part of Belvoir R&D to devote more effort to the neat methanol systems.

RECOMMENDATIONS

Because of the quantity of sulfur which would require removal prior to shift conversion we do not recommend this configuration for further study in small power plants. The inclusion of sufficient quantities of ZnO for sulfur removal would make the power plant too large and heavy. While this is not apparent from the studies pursued under this contract, it is generally accepted that fuels which result in over 200 PPM of hydrogen sulfide in the reformer effluent will require a more elaborate process for sulfur cleanup than ZnO. Such acid gas sweetening systems are too complicated, and large to be incorporated into a mobil power plant. In addition, precious metal catalysts are generally required in the reformer associated with these systems. Conventional nickel catalysts are degraded by the presence of sulfur.

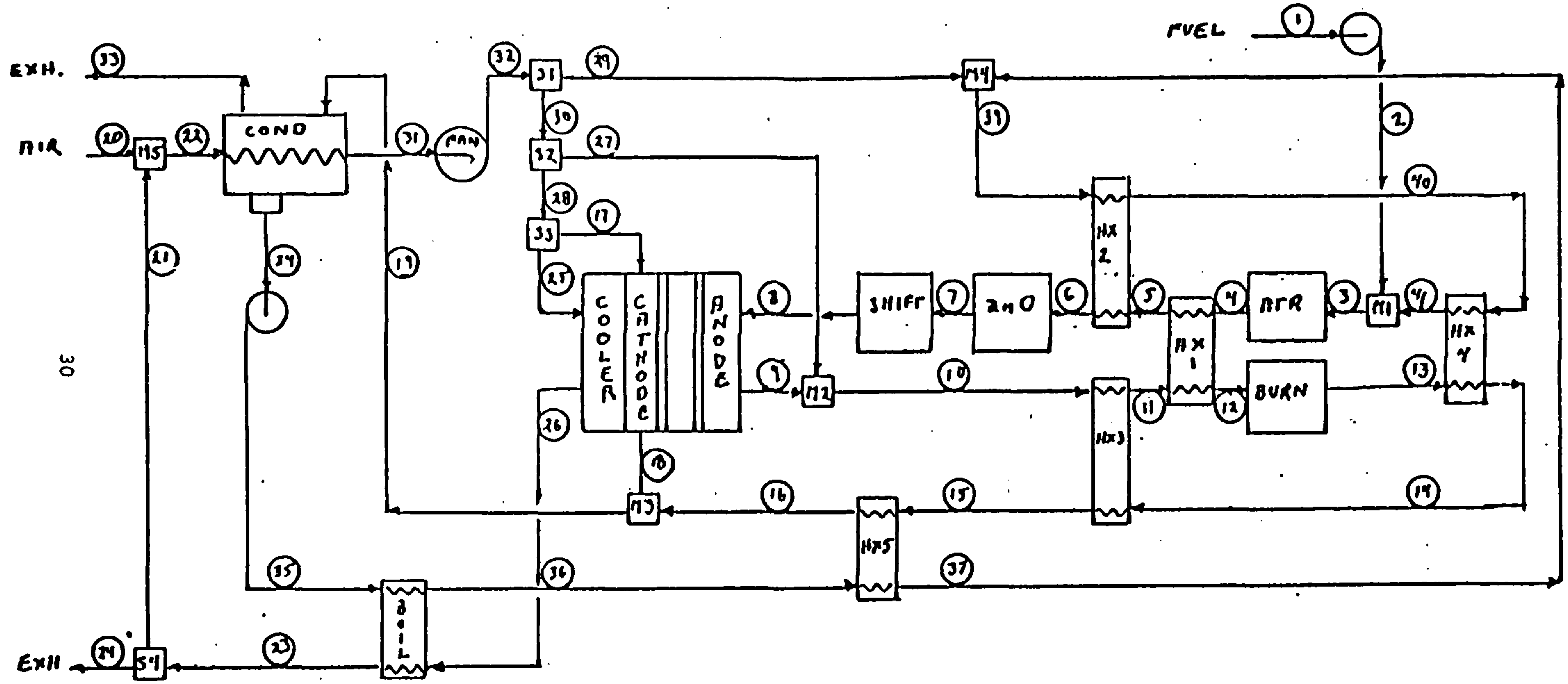

Fig. 2.1 Configuration G041.C ATR/fuel cell power plant conventional water recovery.

TABLE 2.1 PSI/S3E NODE ARRAY

	MOLAR FLOW RATES - lb mole/hr									Press	Temp	Enthalpy	
NODE	H2	H2O	CH4	CO	CO2	O2	N2	FUEL	TOT	ATM	Deg-F	BTU/hr	NODE
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	1
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	2
3	0.0000	0.6480	0.0000	0.0000	0.0000	0.0648	0.2419	0.0144	0.9691	1.0000	1400	-4.9009E+04	3
4	0.3676	0.4532	0.0000	0.1076	0.1084	0.0000	0.2419	0.0000	1.2787	1.0000	1605	-4.9009E+04	4
5	0.3676	0.4532	0.0000	0.1076	0.1084	0.0000	0.2419	0.0000	1.2787	1.0000	1247	-5.3090E+04	5
6	0.3676	0.4532	0.0000	0.1076	0.1084	0.0000	0.2419	0.0000	1.2787	1.0000	891	-5.6971E+04	6
7	0.3676	0.4532	0.0000	0.1076	0.1084	0.0000	0.2419	0.0000	1.2787	1.0000	400	-6.2026E+04	7
8	0.4684	0.3524	0.0000	0.0068	0.2092	0.0000	0.2419	0.0000	1.2787	1.0000	569	-6.2026E+04	8
9	0.1405	0.3524	0.0000	0.0068	0.2092	0.0000	0.2419	0.0000	0.9508	1.0000	375	-6.5889E+04	9
10	0.1405	0.3524	0.0000	0.0068	0.2092	0.0924	0.5867	0.0000	1.3879	1.0000	340	-6.3731E+04	10
11	0.1405	0.3524	0.0000	0.0068	0.2092	0.0924	0.5867	0.0000	1.3879	1.0000	900	-5.7347E+04	11
12	0.1405	0.3524	0.0000	0.0068	0.2092	0.0924	0.5867	0.0000	1.3879	1.0000	1235	-5.3264E+04	12
13	0.0000	0.4929	0.0000	0.0000	0.2160	0.0187	0.5867	0.0000	1.3143	1.0000	2441	-5.3264E+04	13
14	0.0000	0.4929	0.0000	0.0000	0.2160	0.0187	0.5867	0.0000	1.3143	1.0000	1870	-6.0966E+04	14
15	0.0000	0.4929	0.0000	0.0000	0.2160	0.0187	0.5867	0.0000	1.3143	1.0000	1156	-7.0012E+04	15
16	0.0000	0.4929	0.0000	0.0000	0.2160	0.0187	0.5867	0.0000	1.3143	1.0000	943	-7.2549E+04	16
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.3213	1.2122	0.0000	1.5334	1.0000	375	8.9226E+03	17
18	0.0000	0.3213	0.0000	0.0000	0.0000	0.1606	1.2122	0.0000	1,6940	1.0000	375	-2.2891E+04	18
19	0.0000	0.8142	0.0000	0.0000	0.2160	0.1793	1.7989	0.0000	3.0083	1.0000	645	-9.5440E+04	19
20	0.0000	0.0000	0.0000	0.0000	0.0000	5.4815	20.4639	0.0000	25.9454	1.0000	70	9.5525E+04	20
21	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	21
22	0.0000	0.0000	0.0000	0.0000	0.0000	0.4784	1.8050	0.0000	2.2835	1.0000	70	8.4072E+03	22
23	0.0000	0.0000	0.0000	0.0000	0.0000	5.2032	19.4237	0.0000	24.6269	1.0000	300	1.3024E+05	23
24	0.0000	0.0000	0.0000	0.0000	0.0000	5.0000	18.6650	0.0000	0.0000	0.0000	0	0.0000E+00	24
25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	25
26	0.0000	0.0000	0.0000	0.0000	0.0000	5.2032	19.4237	0.0000	24.6269	1.0000	375	1.4330E+05	26
27	0.0000	0.0000	0.0000	0.0000	0.0000	0.0924	0.3448	0.0000	0.4372	1.0000	250	2.1576E+03	27
28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	28
29	0.0000	0.0000	0.0000	0.0000	0.0000	0.0648	0.2419	0.0000	0.3067	1.0000	250	1.5137E+03	29
30	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	30

TABLE 2.1 (CONTINUED) PSI/S3E NODE ARRAY

	MOLAR FLOW RATES - lb mole/hr									Press	Temp	Enthalpy	
NODE	H2	H2O	CH4	CO	CO2	O2	N2	FUEL	TOT	ATM	Deg-F	BTU/hr	NODE
31	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	31
32	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	32
33	0.0000	0.7507	0.0000	0.0000	0.2160	0.1793	1.7989	0.0000	2.9449	1.0000	150	-1.0066E+05	33
34	0.0000	0.0635	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0635	1.0000	150	-7.3744E+03	34
35	0.0000	0.6480	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6480	1.0000	140	-7.5410E+04	35
36	0.0000	0.6480	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6480	1.0000	360	-6.2353E+04	36
37	0.0000	0.6480	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6480	1.0000	813	-5.9817E+04	37
38	0.0000	0.6480	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6480	1.0000	350	-6.2407E+04	38
39	0.0000	0.6480	0.0000	0.0000	0.0000	0.0648	0.2419	0.0000	0.9547	1.0000	321	-6.0894E+04	39
40	0.0000	0.6480	0.0000	0.0000	0.0000	0.0648	0.2419	0.0000	0.9547	1.0000	818	-5.7013E+04	40
41	0.0000	0.6480	0.0000	0.0000	0.0000	0.0648	0.2419	0.0000	0.9547	1.0000	1702	-4.9310E+04	41
42	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	42
43	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	43
44	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	44
45	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	45
46	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	46
47	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	47
48	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	48
49	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	49
50	0.0000	0.8142	0.0000	0.0000	0.2160	0.1793	1.7989	0.0000	3.0083	1.0000	152	-1.0683E+05	50
51	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	51
52	0.0000	0.0000	0.0000	0.0000	0.0000	5.2032	19.4237	0.0000	24.6269	1.0000	370	1.4251E+05	52
53	0.0000	0.0000	0.0000	0.0000	0.0000	5.2032	19.4237	0.0000	24.6269	1.0000	306	1.3119E+05	53
54	0.0000	0.6480	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6480	1.0000	212	-7.4467E+04	54
55	0.0000	0.6480	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6480	1.0000	212	-6.3143E+04	55
56	0.0000	0.6480	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6480	1.0000	360	-6.2353E+04	56
57	0.4684	0.3524	0.0000	0.0068	0.2092	0.0000	0.2419	0.0000	1.2787	1.0000	569	-6.2026E+04	57
58	0.1405	0.3524	0.0000	0.0068	0.2092	0.0924	0.5867	0.0000	1.3879	1.0000	1120	-5.4686E+04	58

CHAPTER 3

CONFIGURATION GO41.D
LIQUID COOLED METHANOL FUELED POWER PLANT
CONDENSING WATER RECOVERY

CHAPTER 3
CONFIGURATION G041.D
LIQUID COOLED METHANOL FUELED POWER PLANT
CONDENSING WATER RECOVERY

INTRODUCTION

This configuration is shown in Fig. 3.1 of this report. The system consists of a liquid cooled fuel cell stack a conventional methanol reformer, a burner (labelled PO for partial oxidizer), two condensers a fan, a fuel pump, two expansion valves and assorted mixers and splitters. In this chapter we will give a description of the system along with a summary of the results obtained and our conclusions and recommendations.

SYSTEM DESCRIPTION

As shown in Fig 3.1, air enters the system at node 13 and is used to cool the water recovery condenser. The heated air is split between the cathode and a waste heat condenser.

Fuel enters the system at node 1 and is mixed with condensate from the water recovery condenser at node 24. The water, methanol mixture is then mixed with water and methanol from the waste heat condenser and the complete mixture is pumped to the cell cooler. Note this is a two phase liquid cooled cell. the mixture of water and methanol leaving the cell cooler is split into two streams; one of which is fed to the waste heat condenser. Note the presence of an expansion valvel. Because the cell operates at 375-400 deg F, the water methanol mixture must be pumped to about 15 atm. This yields a boiling temperature in the range of the cell operating temperature.

The water methanol mixture at node 9 is fed through an expansion valve to the cold side of a methanol reformer. The reformer cold side effluent proceeds to the anode. Anode exhaust is mixed with cathode exhaust and the mixture is supplied to a burner or partial oxidizer. Note that the burner enrichment must be quite low to ensure a high partial pressure of water in the condenser. The hot burner exhaust is fed to the hotside of the methanol reformer and then to the condenser where water is recovered.

The results of the analysis are tabulated in Table 3.1 and Table 3.2. In Table 3.1 we summarize the overall systems parameters associated with the configuration. In Table 3.2, which is an array of the system nodes appearing in Fig 3.1, we summarize the operating conditions which exist throughout the power plant.

RESULTS

The principal advantage of this approach is that the liquid loops in the power plant contain a water/methanol mixture which should not freeze in normal applications. It also is a relatively simple systme which should be relatively easy to start. This

would be accomplished by incorporating a methanol feed to the partial oxidizer along with a glow plug igniter.

Drawbacks to the system are a result of the fact that the water/methanol mixture must be pressurized to permit boiling at temperatures in the range of stack temperature. This requires a relatively high pressure. However, the work required should be low since we are pumping a liquid. Studies were conducted which showed that at the high ambient temperature required (about 125 degF), the water recovery condenser (COND2) would be adequate for condensing the required amount of water. Like the previous system (G041C) the oxygen utilization is controlled by the burner enrichment ratio. Both are restricted to ensure that water recovery can be effected at the temperatures we expect in the condenser. The system was run over a range of air inlet temperatures, the highest being 125 deg F and water would be adequately recovered under these conditions. Under these conditions, the air utilization in the cell was about 76% and the burner operated at stoichiometric conditions.

CONCLUSIONS

While this system appears to be promising, it was not extensively studied. This was due to Ft. Belvoir's interest in non-condensing water recovery systems. The cell stack uses a liquid cooled approach which may be significantly smaller in volume than air cooled systems. The weight of the stack may, however be significant and the relatively high pressures which are found in the methanol loop may be difficult to deal with in a small power plant. Because of the relative simplicity of the approach, it does deserve further study.

RECOMMENDATIONS

Because of the great simplicity, and freeze protection of this approach, we recommend that it receive further study. In particular, it would be adviseable to perform a weight and volume analysis of the power plant.

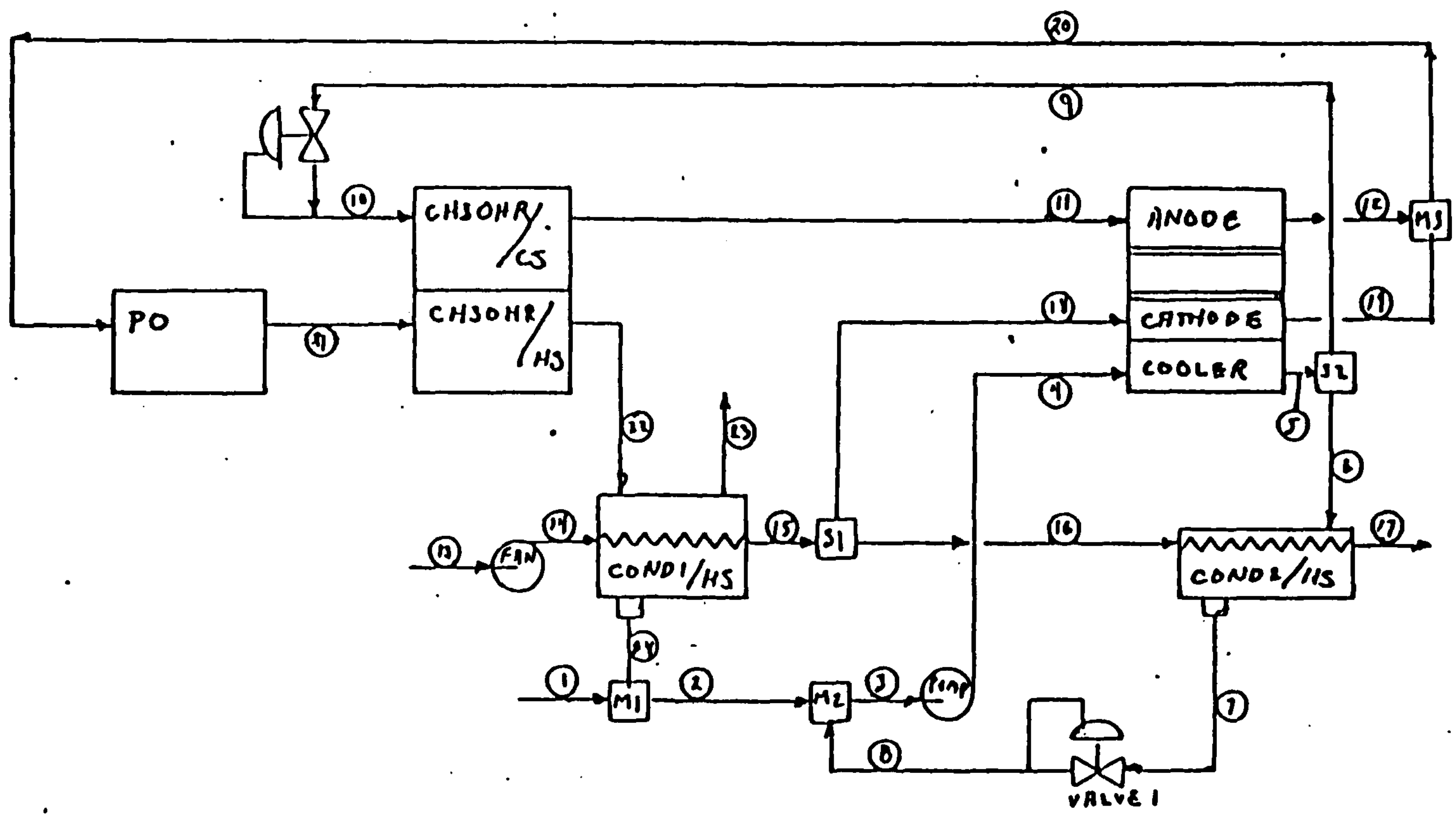

Fig. 3.1 Configuration GO41.D liquid cooled CH3OH fuel cell power plant.

TABLE 3.1 SYSTEM DATA BLOCK

```
POWER (KW)
        NET= 5            GROSS= 7.25   PARASITE= .025
        BLWR= 0           PUMP= 0
        CELL VOLTAGE= .58  CURRENT DENSITY= 166.5678   ASF
        FUEL CELL AREA= 7.504451E-02  SQFT
UTILIZATIONS
        HYDROGEN= .8      AIR(STACK)= .7692308       AIR(SYSTEM)= .9618608
        BURNER ENRICHMENT= .9605172
EFFICIENCY
        OVERALL= .3042115  HEAT RATE= 13008.06        BTU/KWH
        FUEL CELL= .4629999            MECHANICAL= .9950249
        INVERTER= .8      FUEL PROCESSOR= .825412
HX DATA NTU
        CH3OHR= .5939566   FUEL BOILER= 0
        HX-7= 0           HX-9= 0
        COGEN BOILER= 1
HX DATA EFFECTIVENESS
        EF( 4 )= .3703041
        EF( 7 )= .15
QBAL DATA
        Q( 23 )=-27.9961
        Q( 27 )=-942.7695
        Q( 29 )= .2109375
COND DATA
        NC!= .5090789     ND!= 2.801906
        QC= 5568.817      QD= 12701.54

SECANT DATA
K( 1 )= 6     K( 2 )= 27    K( 3 )= 0     K( 4 )= 0     K( 5 )= 51
K( 6 )= 11    K( 7 )= 0     K( 8 )= 0     K( 9 )= 6     K( 10 )= 4
```

TABLE 3.2 PSI/S3E NODE ARRAY

	MOLAR FLOW RATES - lb mole/hr									Press	Temp	Enthalpy	
NODE	H2	H2O	CH4	CO	CO2	O2	N2	FUEL	TOT	ATM	Deg-F	BTU/hr	NODE
1	0.0000	0.2898	0.0000	0.0000	0.0000	0.0000	0.0000	0.2229	0.5127	1.000	70	-4.5741E+04	1
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.000	0	0.0000E+00	2
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.000	0	0.0000E+00	3
4	0.0000	2.4207	0.0000	0.0000	0.0000	0.0000	0.0000	1.8621	4.2828	14.956	345	6.7010E+03	4
5	0.0000	2.4207	0.0000	0.0000	0.0000	0.0000	0.0000	1.8621	4.2828	14.956	345	6.7010E+03	5
6	0.0000	2.1309	0.0000	0.0000	0.0000	0.0000	0.0000	1.6392	3.7701	14.956	345	5.1051E+04	6
7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	14.956	0	0.0000E+00	7
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.000	0	0.0000E+00	8
9	0.0000	0.2898	0.0000	0.0000	0.0000	0.0000	0.0000	0.2229	0.5127	14.956	345	-4.4350E+04	9
10	0.0000	0.2898	0.0000	0.0000	0.0000	0.0000	0.0000	0.2229	0.5127	1.000	345	-4.4350E+04	10
11	0.6425	0.0887	0.0000	0.0196	0.2011	0.0000	0.0000	0.0022	0.9542	1.000	375	-3.8485E+04	11
12	0.1285	0.0887	0.0000	0.0196	0.2011	0.0000	0.0000	0.0022	0.4402	1.000	375	-4.1424E+04	12
13	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.000	0	0.0000E+00	13
14	0.0000	0.0000	0.0000	0.0000	0.0000	5.0000	18.8650	0.0000	23.8650	1.000	70	8.7866E+04	14
15	0.0000	0.0000	0.0000	0.0000	0.0000	5.0000	18.8650	0.0000	23.8650	1.000	180	1.0611E+05	15
16	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.000	0	0.0000E+00	16
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.000	0	0.0000E+00	17
18	0.0000	0.0000	0.0000	0.0000	0.0000	0.3341	1.2607	0.0000	1.5948	1.000	375	9.2795E+03	18
19	0.0000	0.5140	0.0000	0.0000	0.0000	0.0771	1.2607	0.0000	1.8518	1.000	375	-4.1622E+04	19
20	0.1285	0.6027	0.0000	0.0196	0.2011	0.0771	1.2607	0.0022	2.2919	1.000	375	-8.3045E+04	20
21	0.0000	0.7312	0.0000	0.0000	0.2207	0.0030	1.2607	0.0022	2.2179	1.000	1231	-8.3043E+04	21
22	0.0000	0.7312	0.0000	0.0000	0.2207	0.0030	1.2607	0.0022	2.2179	1.000	877	-8.9850E+04	22
23	0.0000	0.4404	0.0000	0.0000	0.2207	0.0030	1.2607	0.0022	1.9270	1.000	146	-7.4306E+04	23
24	0.0000	0.2908	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2908	1.000	146	-3.3815E+04	24
25	0.0000	0.0000	0.0000	0.0000	0.0000	0.3341	1.2607	0.0000	1.5948	1.000	70	5.8715E+03	25
26	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0	0.0000E+00	26
27	0.6425	0.0887	0.0000	0.0196	0.2011	0.0000	0.0000	0.0022	0.9542	1.000	500	-3.7543E+04	27
28	0.0000	0.5652	0.0000	0.0000	0.0000	0.0000	0.0000	0.4348	1.0000	14.956	345	-8.6495E+04	28
29	0.0000	0.7312	0.0000	0.0000	0.2207	0.0030	1.2607	0.0022	2.2179	1.000	161	-1.0255E+05	29

CHAPTER 4

CONFIGURATION G041E
AIR COOLED METHANOL FUELED POWER PLANT
CONDENSING WATER RECOVERY

CHAPTER 4
CONFIGURATION G041E
AIR COOLED METHANOL FUELED POWER PLANT
CONDENSING WATER RECOVERY

INTRODUCTION

In this chapter we will discuss an air cooled, methanol fueled power plant. The power plant employs condensing water recovery. Two configurations were developed in the course of this analysis. The first is shown in Fig 4.1. This configuration, designated G041E, required modification because the stack air inlet temperature was too low. A modification to the approach was developed and is shown in figure 4.2. This was designated G041E1. The modified approach was capable of delivering 250 deg F air to the cooling air and cathode gas passages of the cell stack.

In the course of this program development we prepared several advanced graphics displays which will assist the analyst in the evaluation of this type of air cooled, condensing water recovery unit. Examples of the types of "On-Line" displays are shown in Figures 4.3 through 4.5. We did not extend the analysis to include intensive parametric analysis as Ft. Belvoir expressed an interest in non-condensing water recovery systems using neat methanol.

After the description of the configuration, we have given a summary of the results of our studies along with conclusions and recommendations.

SYSTEM DESCRIPTION

A description of the system is as follows; we will describe the G041E1 configuration only. As noted in the system schematic, Fig 4.2, the power plant is quite simple and somewhat similar to the previously described system G041D. Air enters the water recovery condenser where it is preheated. The condenser air effluent is mixed with boiler effluent air and is fed to a fan. The purpose of the mixing process is to preheat the air to about 250 degrees prior to feeding it to the cell stack. The air is split into two streams, one of which is fed to the cell coolers and the other to the cathode.

Cell cooler effluent air is then fed to a methanol/water boiler where it is preheated to about 320 deg F. The vaporized mixture is next fed to the cold side of a conventional methanol reformer and the cooled effluent is fed to the fuel cell anode. The anode exhaust is mixed with cathode effluent and the mixture is next fed to a partial oxidizer/burner. The burner exhaust is fed to the hot side of the reformer prior to being condensed in the water recovery condenser.

RESULTS

This system analyzed showed that it could operate under high ambient temperatures with reasonable utilizations. The results are summarized in Table 4.1 which is a summary of the system parameters associated with the revised configuration shown in Fig. 4.2. The thermodynamic properties which exist at the nodes corresponding to this configuration are found in Table 4.2. Because of Belvoir R&D interest in non-condensing systems, the approach was not subjected to the parametric analysis used for configuration G041G.

The developement of the graphic displays were conducted in this task which are of great aid in analyzing fuel cell power plants.

CONCLUSIONS

The G041E1 configuration is an adequate approach to air cooled methanol (neat) fueled fuel cell power plants. Its drawbacks are similar to any condensing approach in that freezing of water in the condenser under low temperature conditions is possible. Nevertheless, the system is quite simple and should represent a lightweight approach to power plant construction.

RECOMMENDATIONS

This configuration will be of interest only if the Army interest in condensing systems is revived. Otherwise, no further analysis is required.

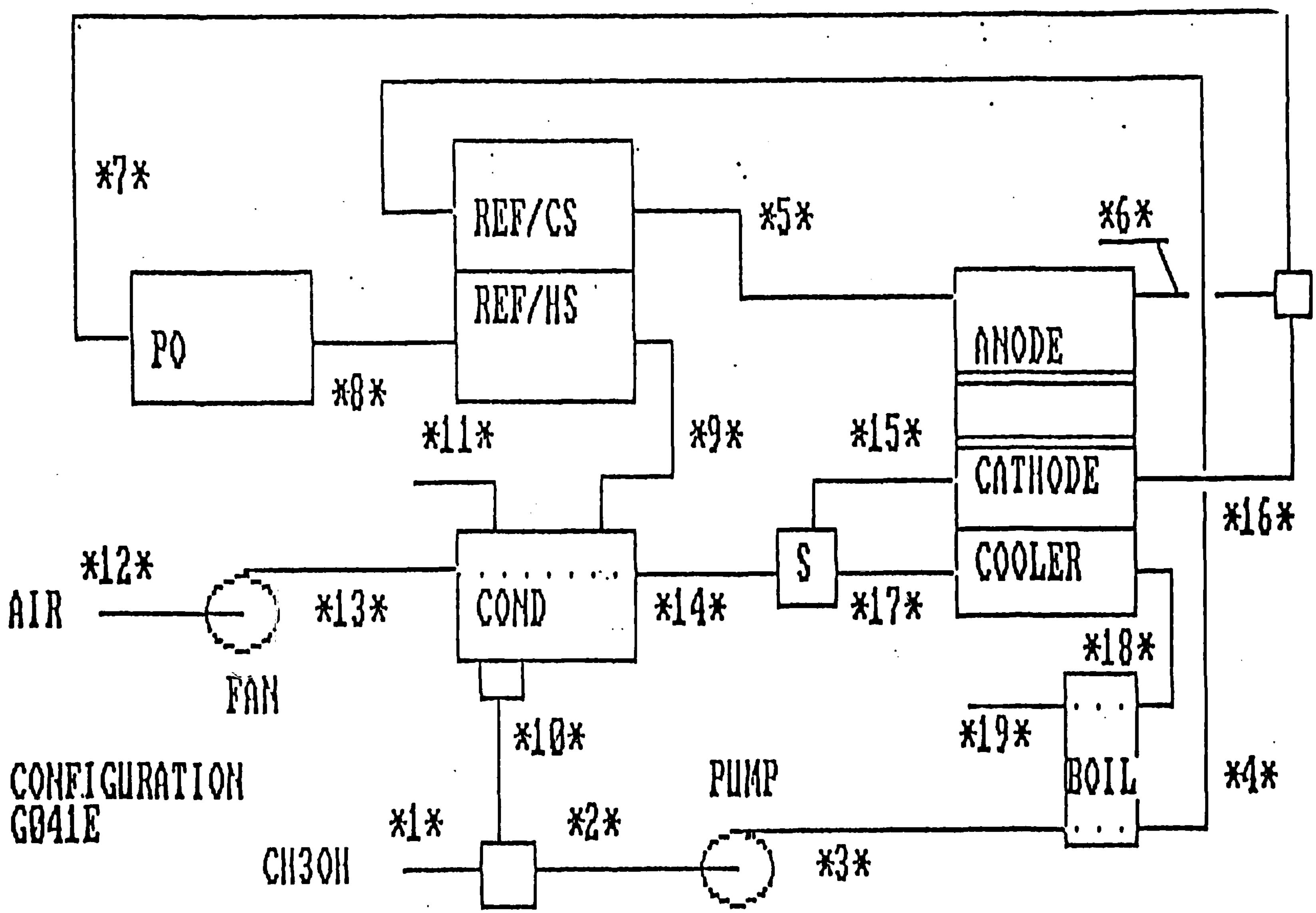

Fig. 4.1 Original G041E configuration.

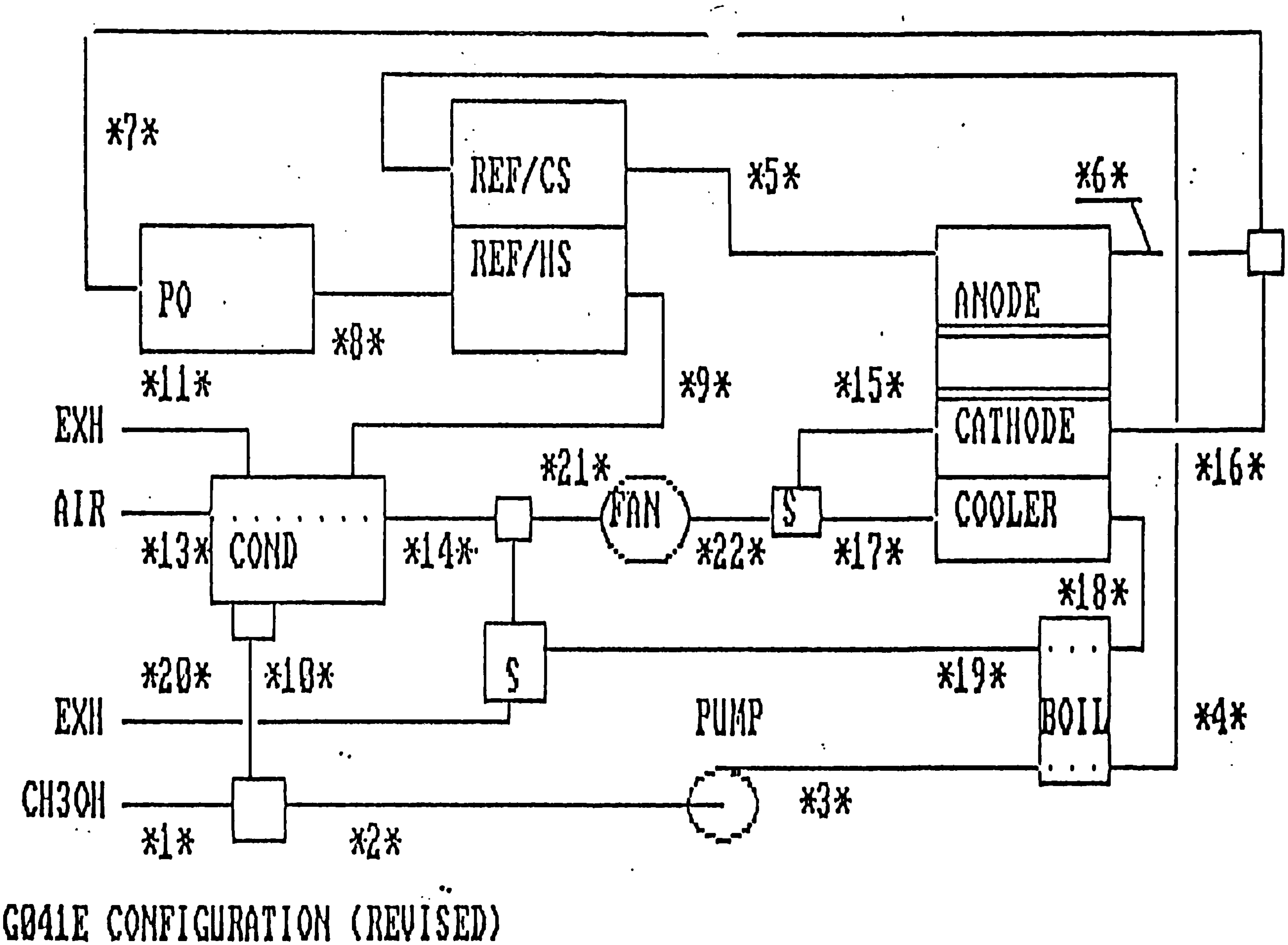

Fig. 4.2 Revised G041E configuration.

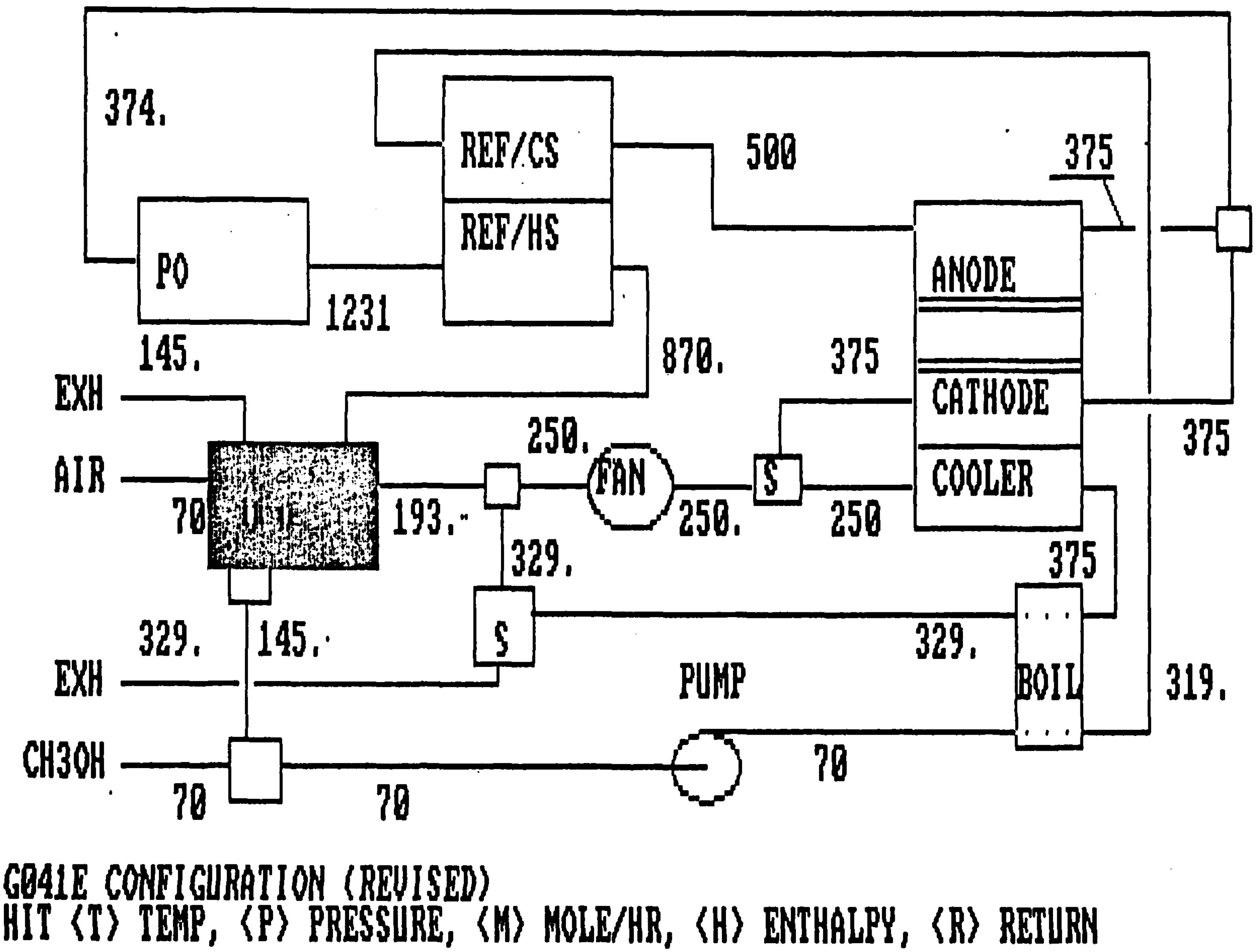

Fig. 4.3 Configuration G041E showing on-line display of power plant node temperatures.

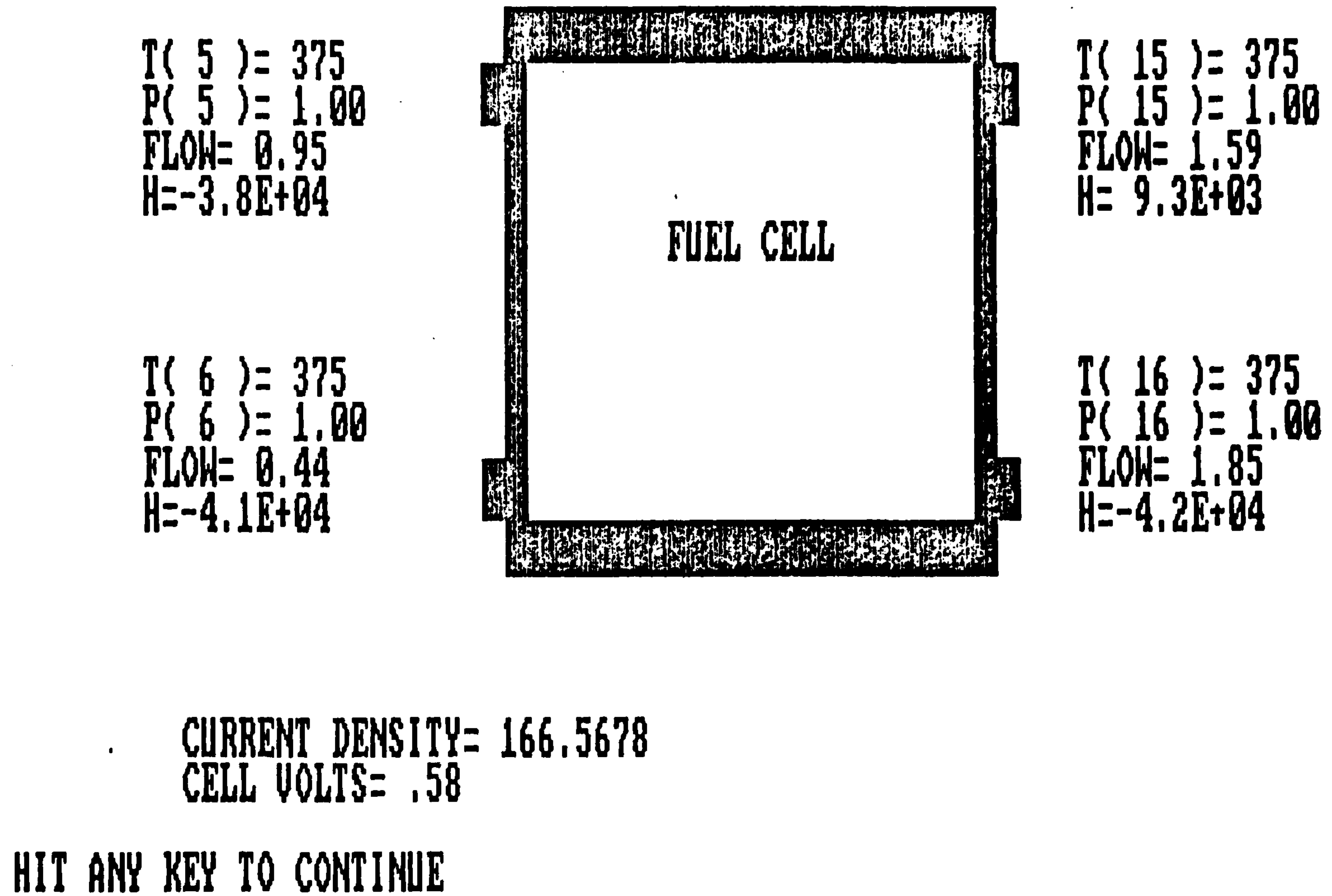

Fig. 4.4 On-line display of fuel cell.

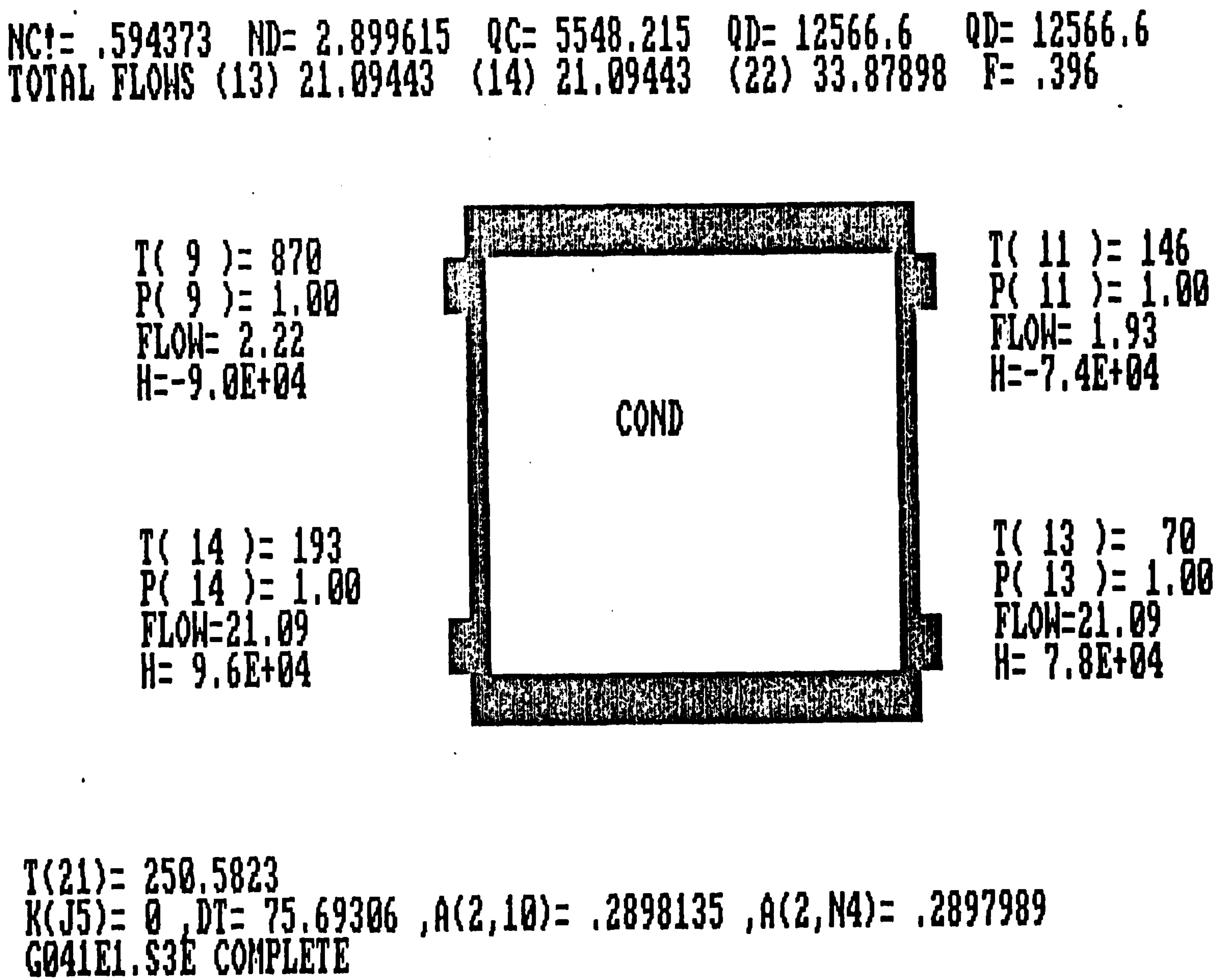

Fig. 4.5 On-line display of condenser.

TABLE 4.1 SYSTEM DATA BLOCK

```
POWER (KW)
          NET= 5                GROSS= 7.25   PARASITE= .8
          CELL VOLTAGE= .58  CURRENT DENSITY= 166.5678   ASF
          FUEL CELL AREA= 75.04451  SQFT
          AMP= 233.1949
                     STACK VOLTS= 31.32
          NUMBER OF CELLS= 54

UTILIZATIONS
          HYDROGEN= .8         AIR(STACK)= .7692308
          BURNER ENRICHMENT= 1.2
EFFICIENCY
          OVERALL= .2635625  HEAT RATE= 15014.27         BTU/KWH
          FUEL CELL= .4629999               MECHANICAL= .8620689
          INVERTER= .8         FUEL PROCESSOR= .825412


HIT ANY KEY TO CONTINUE
```

TABLE 4.1 (CONTINUED)

```
REFORMER DATA
         REFORMER NTU= .6014306            HEAT DUTY= 6942.281  BTU/HR
         REFORMER HEAT TRANSFER AREA=-2.319607  FT2
BOILER DATA
         NTU= 1.998927      AREA= 1.274575  FT2
         BOILER HEAT DUTY= 10487.7  BTU/HR
         FAN CFM= 214.2846
         PUMP GPH= 1.153681
QBAL DATA
         Q(5)=-942.7695
COND DATA
         NC!= .594373      ND!= 2.899615
         QC= 5548.215  BTU/HR              QD= 12566.6 BTU/HR
                  CONDENSER AREA= 6.003259  FT2        HEAT DUTY= 18083.63
BTU/HR
SECANT DATA
K( 1 )= 6     K( 2 )= 26    K( 3 )= 0     K( 4 )= 0     K( 5 )= 6

K( 6 )= 15    K( 7 )= 3     K( 8 )= 0     K( 9 )= 6     K( 10 )= 7




HIT ANY KEY TO CONTINUE
```

TABLE 4.2 PSI/S3E NODE ARRAY

	MOLAR FLOW RATES - lb mole/hr									Press	Temp	Enthalpy	
NODE	H2	H2O	CH4	CO	CO2	O2	N2	FUEL	TOT	ATM	Deg-F	BTU/hr	NODE
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2229	0.2229	1.000	70	-2.0855E+04	1
2	0.0000	0.2898	0.0000	0.0000	0.0000	0.0000	0.0000	0.2229	0.5127	1.000	70	-5.4973E+04	2
3	0.0000	0.2898	0.0000	0.0000	0.0000	0.0000	0.0000	0.2229	0.5127	1.000	70	-5.4973E+04	3
4	0.0000	0.2898	0.0000	0.0000	0.0000	0.0000	0.0000	0.2229	0.5127	1.000	320	-4.4485E+04	4
5	0.6425	0.0887	0.0000	0.0196	0.2011	0.0000	0.0000	0.0022	0.9542	1.000	375	-3.8485E+04	5
6	0.1285	0.0887	0.0000	0.0196	0.2011	0.0000	0.0000	0.0022	0.4402	1.000	375	-4.1424E+04	6
7	0.1285	0.6027	0.0000	0.0196	0.2011	0.0771	1.2607	0.0022	2.2919	1.000	375	-8.3045E+04	7
8	0.0000	0.7312	0.0000	0.0000	0.2207	0.0030	1.2607	0.0022	2.2179	1.000	1231	-8.3043E+04	8
9	0.0000	0.7312	0.0000	0.0000	0.2207	0.0030	1.2607	0.0022	2.2179	1.000	870	-8.9985E+04	9
10	0.0000	0.2898	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2898	1.000	146	-3.3693E+04	10
11	0.0000	0.4414	0.0000	0.0000	0.2207	0.0030	1.2607	0.0022	1.9281	1.000	146	-7.4407E+04	11
12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.000	0	0.0000E+00	12
13	0.0000	0.0000	0.0000	0.0000	0.0000	4.4193	16.6752	0.0000	21.0944	1.000	70	7.7665E+04	13
14	0.0000	0.0000	0.0000	0.0000	0.0000	4.4193	16.6752	0.0000	21.0944	1.000	193	9.5749E+04	14
15	0.0000	0.0000	0.0000	0.0000	0.0000	0.3341	1.2607	0.0000	1.5948	1.000	375	9.2795E+03	15
16	0.0000	0.5140	0.0000	0.0000	0.0000	0.0771	1.2607	0.0000	1.8518	1.000	375	-4.1622E+04	16
17	0.0000	0.0000	0.0000	0.0000	0.0000	6.7635	25.5207	0.0000	32.2842	1.000	250	1.5934E+05	17
18	0.0000	0.0000	0.0000	0.0000	0.0000	6.7635	25.5207	0.0000	32.2842	1.000	375	1.8785E+05	18
19	0.0000	0.0000	0.0000	0.0000	0.0000	6.7635	25.5207	0.0000	32.2842	1.000	329	1.7737E+05	19
20	0.0000	0.0000	0.0000	0.0000	0.0000	4.0852	15.4145	0.0000	19.4997	1.000	329	1.0713E+05	20
21	0.0000	0.0000	0.0000	0.0000	0.0000	7.0976	26.7813	0.0000	33.8790	1.000	251	1.6735E+05	21
22	0.0000	0.0000	0.0000	0.0000	0.0000	7.0976	26.7813	0.0000	33.8790	1.000	251	1.6735E+05	22
23	0.0000	0.0000	0.0000	0.0000	0.0000	2.6784	10.1062	0.0000	12.7846	1.000	329	7.0237E+04	23
24	0.0000	0.2898	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2898	1.000	146	-3.3693E+04	24
25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.000	0	0.0000E+00	25
26	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0	0.0000E+00	26
27	0.6425	0.0887	0.0000	0.0196	0.2011	0.0000	0.0000	0.0022	0.9542	1.000	500	-3.7543E+04	27
28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0	0.0000E+00	28
29	0.0000	0.7312	0.0000	0.0000	0.2207	0.0030	1.2607	0.0022	2.2179	1.000	161	-1.0255E+05	29
30	0.0000	0.0000	0.0000	0.0000	0.0000	4.4193	16.6752	0.0000	21.0944	1.000	108	8.3182E+04	30

CHAPTER 5

CONFIGURATION G041F
AIR COOLED METHANOL FUELED POWER PLANT
NON-CONDENSING WATER RECOVERY

CHAPTER 5
CONFIGURATION G041F
AIR COOLED METHANOL FUELED POWER PLANT
NON-CONDENSING WATER RECOVERY

INTRODUCTION

The G041F configuration uses catalytically partial oxidation to oxidize methanol, and uses burner exhaust to preheat the inlet air to about 250 deg F. This power plant is shown in Fig 5.1. The configuration was not analyzed extensively because of its relatively poor operating characteristics. In this chapter we present the system description along with a summary of results, conclusions and recommendations.

SYSTEM DESCRIPTION

In describing the flow through the system shown in Fig 5.1 we start with the air side of the power plant. Air is fed to the power plant via a fan and is immediately mixed with burner exhaust. The burner exhaust raises the temperature of the air to about 250 deg F. Note that for power plants of about 5kW operating at a cell voltage of 0.58 the cooling air flow must be about 30 lb-moles/hr. After proceeding through the cell coolers where it is heated to about cell temperature, the cooler effluent proceeds through three splitters. The first of these directs air to the cathode, the second provides burner air and the third provides air to the autothermal reformer. Because the water content of this stream is quite low, the we are actually referring to a catalytic partial oxidizer, rather than a true auto thermal reformer. The reformer air supply is mixed with fuel.

Because of the relatively small amount of nitrogen and low heat content of the reformer air stream, the methanol is not fully vaporized in this mixing process. The methanol air mixture is fed to a heat exchanger where the stream is heated to reformer inlet temperature with autothermal reformer exhaust.

Note that Fig 5.1 shows an ATR as the fuel processor. While we use the ATR model in this analysis, the unit is actually a catalytic partial oxidizer. In general the use of the term Autothermal Reforming implies that the fuel is mixed with steam prior to entry into the reactor. This is clearly not the case in this system.

In our analyses the ATR inlet temperature is most probably too low to be practical. The ATR effluent proceeds to a heat exchanger and then via a mass transfer unit to the shift converter. We have included a mass transfer unit which selectively transfers water vapor from the cathode exhaust to the shift converter inlet stream. Such a unit is a simple filter press design where the filters are impregnated with phosphoric acid. The permanent gases have a low solubility in the acid but water vapor has a high solubility. Hence water vapor in the

cathode exhaust is transferred to the dry stream from the ATR.

Without the mass transfer device, the ATR exhaust has a concentration of almost 20% CO, clearly too high for use in a fuel cell. Moreover the degree of shift which would occur in the stream is negligibile. With the mass transfer unit as shown, the CO concentration is reduced to about 4.5%. This is still a fairly high level for use in the fuel cell anode.

The shifted gas proceeds through the anode and thence to a mixer for eventual use in the burner.

RESULTS

The efficiency of this power plant is quite low, on the order of 15%. There are several reasons for this. First, the hydrogen utilization is required to be on the order of 0.6. This limits fuel processor efficiency. Note that almost no burner waste heat is fed to the fuel processor. This, in turn means that the heat release required in the ATR must supply not only the methanol reforming energy but a considerable degree of preheat. The result is that the O2/C ratio required by the system must be greater than 0.3. Hence a great degree of fuel energy is required by the fuel processor. This directly results in a low efficiency.

In addition to the problems mentioned above, we note that the CO concentration is quite high in the ATR effluent. This is directly due to the low concentration of water in the inlet stream to the ATR. The problem is compounded by the shift converter. The use of supplemental water addition to this system to convert the large CO concentration from the ATR to H2 which the cell could use results in a large heat release in the shift converter. The net effect is that we have a high shift converter exit temperature with, concomittantly high CO concentrations and a high anode inlet temperature.

We could concievably reduce the amount of burner heat required by the air preheater by increasing the cell voltage. This would, unfortunately require a large cell stack.

CONCLUSIONS

Because of the unpromising results obtained in the preliminary investigation, this system was not extensively explored via the parametric approach we used in the G041G system. At low pressures, insufficient water is transferred to the shift converter inlet. At elevated pressures, this condition could be altered somewhat. As we will discuss in Chapter 6, turbocharging of small air cooled power plants is not out of the question. Under higher pressure conditions the degree of shift conversion should improve because cathode exhaust will have a higher dewpoint and more water will be transferred across the shift inlet humidifier.

RECOMMENDATIONS

It is recommended that this configuration be re-evaluated under pressurized conditions.

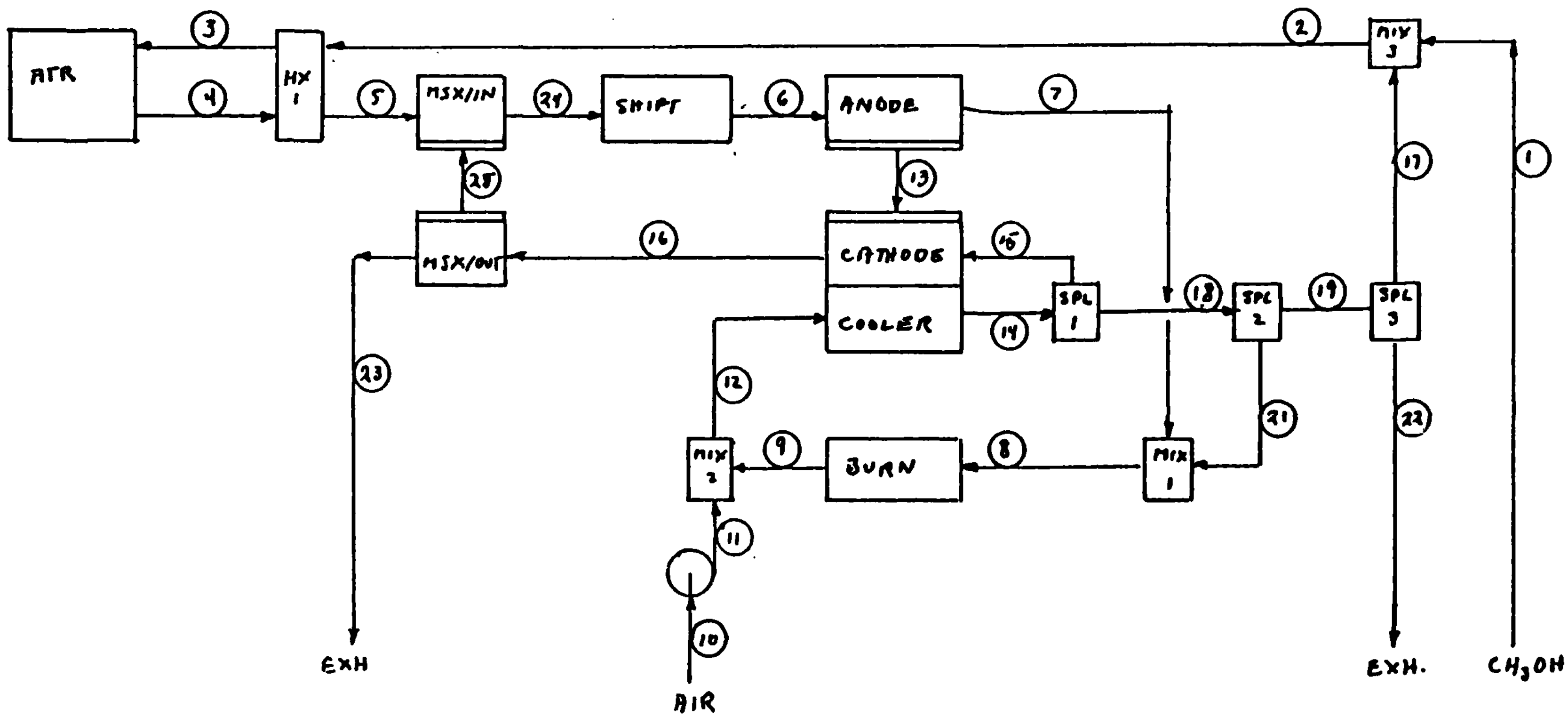

Fig. 5.1 Configuration GO41F.

TABLE 5.1 SYSTEM DATA BLOCK

```
PARAMETRIC STUDY PARAMETERS

ATR O2/C=  .3
HYDROGEN UTILIZATION  .6
CELL VOLTS = .58
AIR INLET TEMP= 70
ATR EXIT TEMP, DEFAULT = 1400
POWER (KW)
         NET= 5                GROSS= 7.25   PARASITE= .8
         CELL VOLTAGE= .58  CURRENT DENSITY= 149.8099   ASF
         FUEL CELL AREA= 83.43909  SQFT
         NUMBER OF CELLS @ 1.4 FT2= 60
         STACK VOLTS= 34.8
         STACK CURRENT= 209.7338 ;AMP

         CELL TEMPERATURE= 375 DEG F
UTILIZATIONS
         HYDROGEN= .6        AIR(STACK)= .6
         BURNER ENRICHMENT= 1.2

ATR FUEL PROCESSOR OUTPUT
WATER TO FUEL RATIO= 1.814008E-02         O2/FUEL RATIO= .3
EFFICIENCY
         OVERALL= .148196
         FUEL CELL= .4629999                  MECHANICAL= .862069
         INVERTER= .8        FUEL PROCESSOR= .4641129

HX DATA NTU
         HX-1= 3
HEAT EXCHANGER AREA
                   HX 1 AREA= 2.748049  FT2
QBAL DATA

SECANT DATA
K( 1 )= 225   K( 2 )= 140   K( 3 )= 40    K( 4 )= 0     K( 5 )= 0
K( 6 )= 35    K( 7 )= 2     K( 8 )= 7     K( 9 )= 0     K( 10 )= 0    K( 11 )= 0
```

TABLE 5.2 PSI/S3E NODE ARRAY

	MOLAR FLOW RATES - lb mole/hr									Press	Temp	Enthalpy	
NODE	H2	H2O	CH4	CO	CO2	O2	N2	FUEL	TOT	ATM	Deg-F	BTU/hr	NODE
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3962	0.2857	1.000	70	-3.7060E+04	1
2	0.0001	0.0072	0.0000	0.0001	0.0063	0.1188	0.4683	0.3962	0.8865	1.000	160	-3.5398E+04	2
3	0.0001	0.0072	0.0000	0.0001	0.0063	0.1188	0.4683	0.3962	0.8865	1.000	310	-2.7953E+04	3
4	0.6717	0.1279	0.0000	0.2793	0.1233	0.0000	0.4683	0.0000	1.6705	1.000	1142	-2.7953E+04	4
5	0.6717	0.1279	0.0000	0.2793	0.1233	0.0000	0.4683	0.0000	1.6705	1.000	567	-3.5395E+04	5
6	0.8566	0.0881	0.0000	0.0944	0.3082	0.0000	0.4683	0.0000	1.8156	1.000	602	-5.1726E+04	6
7	0.3427	0.0881	0.0000	0.0944	0.3082	0.0000	0.4683	0.0000	1.3017	1.000	375	-5.7855E+04	7
8	0.3429	0.1032	0.0000	0.0947	0.3213	0.2500	1.4533	0.0000	2.5655	1.000	370	-5.4360E+04	8
9	0.0000	0.4462	0.0000	0.0000	0.4160	0.0312	1.4533	0.0000	2.3467	1.000	2581	-5.4360E+04	9
10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.000	0	0.0000E+00	10
11	0.0000	0.0000	0.0000	0.0000	0.0000	7.2592	27.3908	0.0000	34.6500	1.000	70	1.2757E+05	11
12	0.0073	0.4389	0.0000	0.0080	0.3827	7.2592	28.6038	0.0000	36.7000	1.000	255	7.2813E+04	12
13	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.000	0	0.0000E+00	13
14	0.0073	0.4389	0.0000	0.0080	0.3827	7.2592	28.6038	0.0000	36.7000	1.000	365	1.0151E+05	14
15	0.0004	0.0254	0.0000	0.0005	0.0221	0.4193	1.6523	0.0000	2.1199	1.000	365	5.8637E+03	15
16	0.0004	0.5032	0.0000	0.0005	0.0221	0.1677	1.6523	0.0000	2.3462	1.000	375	-4.1380E+04	16
17	0.0001	0.0072	0.0000	0.0001	0.0063	0.1188	0.4683	0.0000	0.6009	1.000	365	1.6620E+03	17
18	0.0069	0.4136	0.0000	0.0075	0.3606	6.8399	26.9516	0.0000	34.5800	1.000	365	9.5648E+04	18
19	0.0066	0.3985	0.0000	0.0072	0.3475	6.5899	25.9665	0.0000	33.3162	1.000	365	9.2152E+04	19
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.000	0	0.0000E+00	20
21	0.0003	0.0151	0.0000	0.0003	0.0132	0.2500	0.9850	0.0000	1.2638	1.000	365	3.4957E+03	21
22	0.0065	0.3913	0.0000	0.0071	0.3412	6.4710	25.4982	0.0000	32.7153	1.000	365	9.0490E+04	22
23	0.0004	0.3580	0.0000	0.0005	0.0221	0.1677	1.6523	0.0000	2.2010	1.000	375	-2.7432E+04	23
24	0.6717	0.2730	0.0000	0.2793	0.1233	0.0000	0.4683	0.0000	1.8156	1.000	375	-5.1726E+04	24
25	0.0000	0.1451	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1451	1.000	375	-1.3948E+04	25

CHAPTER 6

CONFIGURATION G041C
AIR COOLED METHANOL FUELED POWER PLANT
CATHODE RECYCLE WATER RECOVERY

CHAPTER 6
CONFIGURATION G041G
AIR COOLED METHANOL FUELED POWER PLANT
CATHODE RECYCLE WATER RECOVERY

INTRODUCTION

Our objective in developing this configuration which is shown in Fig 6.1 was to develop and analyze a power plant configuration which will function on neat methanol and which makes use of an autothermal reformer. Because of the advantages shown by this approach, we also tried to determine the variation of power plant performance with various operating conditions. This configuration was subjected to the most extensive analysis of all of the configurations developed during the course of the study. The methods employed in the study are found in Appendix 2. In this section we will provide a system description along with the results of our findings, conclusions and recommendations.

SYSTEM DESCRIPTION

The system configured is shown in Fig. 6.1. In this section we will briefly describe the system flow. We start at node 1 with input methanol. The methanol is mixed with heated cathode exhaust from node 17. The output of this mixer, which also vaporizes the fuel is fed to a heat exchanger (HX1) which serves to preheat the mixture prior to its entry into the ATR at node 3. The reformed methanol mixture leaves the ATR at node 4 and enters a heat exchanger (HX2) which serves to cool the mixture prior to its entry into the shift converter. As previously mentioned, HX2 also serves to preheat the cathode exhaust.

In the analysis we attempt to cool the mixture to 400 deg F. This is obviously not possible given the ATR and fuel cell temperatures. We assume that heat can be dumped at node 5 so that the inlet temperature to the shift converter is about 400 deg F. The shift effluent is fed directly to the anode, and the effluent from the anode at node 7 then proceeds to the burner via a mixer. The burner effluent is used in HX1 to preheat the ATR inlet stream 3.

The air loop starts with the inlet at node 11. We then proceed through a mixer. In the mixer, a portion of the cell cooler exhaust is recycled to the mixer to preheat the cooler inlet stream to 250 deg F. Proceeding through the cooler, the effluent at node 14 is split into cathode feed at node 15, recycle at node 19, and to burner air at node 21. The remaining air is exhausted at node 22.

Table 6.1 shows a typical output from the computer model. During the course of the parametric studies conducted, we summarized this type of systems output into tabular data which were used in conjunction with a spreadsheet code. Table 6.2 shows a set of typical node array data showing the thermodynamic conditions at all points in the power plant.

G041G2 PARAMETRICS

A parametric study of the power plant configuration shown in Fig 6.1 was conducted. The objective of the study was to determine the set of optimum design and operating conditions. The optimum conditions are assumed to be those which yield a minimum volume in an allowable overall power plant efficiency range. In the parametric study performed, we varied the following:

Parameter	Range
O2/C ratio (PSI)	0.2 - 0.15 - 0.1
Hydrogen utilization (UH) from	0.6 - 0.65 - 0.7
Cell Volts (VO)	0.58- 0.60 - 0.625 - 0.65
Ambient Temperature T(L2)	70 - 90 - 105 - 125
ATR exit Temperature TATR	1400-1200 - 1000 - 800

In a nested form this yields 576 cases. Of this number, 433 cases were successfully resolved. Failures are attributable principally to impossible operating conditions. Some code errors may have resulted which caused failures.

PARAMETRIC STUDY RESULTS

The major findings of the parametric study results are shown in Table 6.3. This table was created with the G041G2.WKS code. As shown in the table, of the 433 successful cases run, the optimum design occurs at the following conditions:

O2/C	0.15
UH	0.65
VO	0.58 volts
T(L2)	70-125 deg F
TATR	800 deg F

The optimum condition is determined as the lowest volume case. The system data is also included in Table 6.3.

In Table 6.4 we show those cases having the highest overall efficiency. From the table we note that this efficiency is 27.1%. Because the stack areas of these systems were very large, due to the high cell voltage, we examined the case of powerplants having efficiencies above 20% and having the smallest stack areas. Note that these all occur at cell voltages of 0.58 as one would expect. These results are shown in Table 3.

It is also interesting to note that most of the cases of both low volume and high efficiency occured at the lower values of ATR exit temperature. In fact of the ten cases examined for lowest volume no ATR temperature other than 800 deg F was noted. As noted in table 1, in order to obtain a small power plant, the cell voltage must be a minimum.

CONCLUSIONS

While the results of the study appear to be encouraging, several questions arise in conjucntion with the feasiblity of operating a real power plant at the conditions shown. We first address the question of cathode air utilization. In all optimum cases, the air utilization is above 84%. The PSI/S3E fuel cell model is a steady state model of the power plant. While it calculates the effect of oxygen partial pressure on cell performance, it does not address the problem of flow maldistribution between cells. Certainly, at high utilizations this is an important consideration.

In the autothermal reforming case, the oxygen utilization is determined by the oxygen to carbon ratio required in the autothermal reformer. Specifically, the oxygen to carbon ratio will determine the ATR exit temperature. It is not an independent parameter. While we could bleed air off at the cathode exit, this would reduce the water available to the autothermal reformer. The result would be more CO production and lower efficiency in the fuel processor. Another alternative would be to pressurize the process. Generally this has not been considered attractive in the past because commercially available turbochargers do not have the low flow capacity required by low power power plants.

Since the power plant is air cooled, we may consider turbocharging of both the cooling and process air. This increase in turbocharger flow rate makes pressurized operation feasible. Moreover, with commercially available turbochargers, a compressor exit temperature of about 250 deg F would be attained. This would permit the elimination of the recycle air preheat system shown in configuration G.

Next, the use of an autothermal reformer could result in the production of methane if conventional nickel catalysts were used. An autothermal reformer catalyst which suppresses methane formation is required. While it has not been tested under autothermal reforming conditions, Engelhard has developed a catalyst which shows the required reforming properties at the temperatures of interest.

Another important question is; assuming that the system will function properly at the rated power point, it is not known how the system will react at reduced power levels. A concern is that while water evolution occurs at the cathode under high load conditions, this becomes less true at reduced power levels. Under these conditions, the anode and cathode water vapor concentrations tend to equilibrate. The result of this equilibration will be a reduction of the steam delivered to the autothermal reformer and a reduction in its efficiency. At the present time we have not analyzed the extent of this effect.

RECOMMENDATIONS

Because of the gains to be made through the use of turbocharging, it is recommended that this configuration be recast in a turbocharged configuration. In addition to the conventional design point operation study, an off-design study should be conducted to determine how the power plant performs at low load.

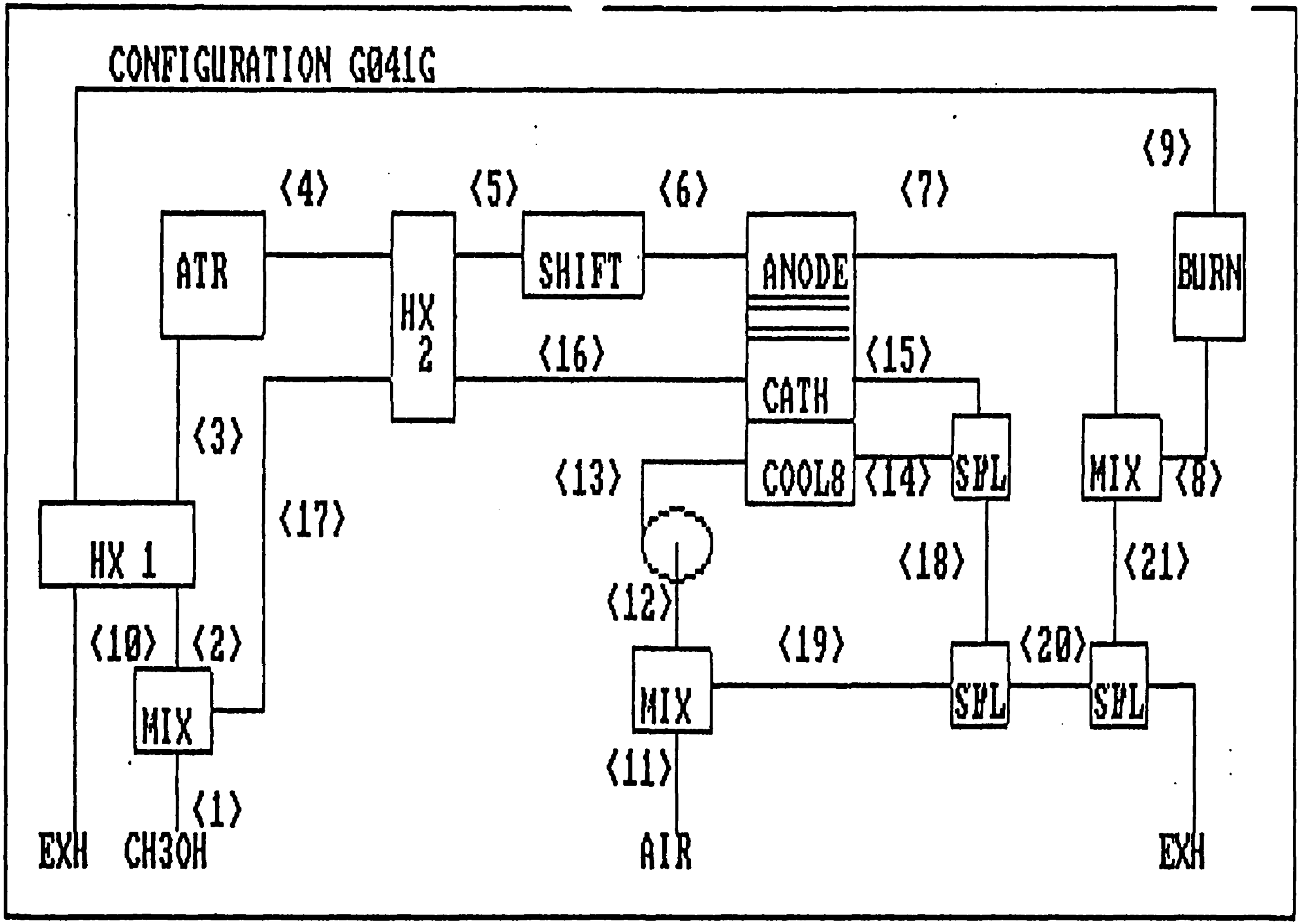

Fig. 6.1 Configuration GO41G.

TABLE 6.1 SYSTEM DATA BLOCK

```
PARAMETRIC STUDY PARAMETERS

ATR O2/C=  .2
HYDROGEN UTILIZATION  .6
CELL VOLTS = .58
AIR INLET TEMP= 70
ATR EXIT TEMP, DEFAULT = 800
POWER (KW)
         NET= 5                 GROSS= 7.25   PARASITE= .8
         CELL VOLTAGE= .58  CURRENT DENSITY= 155.1461   ASF
         FUEL CELL AREA= 80.56923  SQFT
         NUMBER OF CELLS @ 1.4 FT2= 58
         STACK VOLTS= 33.64
         STACK CURRENT= 217.2045 ;AMP

         CELL TEMPERATURE= 375 DEG F
UTILIZATIONS
         HYDROGEN= .6        AIR(STACK)= .7715096
         BURNER ENRICHMENT= 1.2

ATR FUEL PROCESSOR OUTPUT
WATER TO FUEL RATIO= 1.350621            O2/FUEL RATIO= .2
EFFICIENCY
         OVERALL= .1811391
         FUEL CELL= .4629999             MECHANICAL= .8620689
         INVERTER= .8       FUEL PROCESSOR= .5672823

 X DATA NTU
         HX-1= .1939107     HX-2= 9.255756
HEAT EXCHANGER AREA
                    HX 1 AREA= 3.170811  FT2            HX 2 AREA= 110.8781  FT2

QBAL DATA
         Q( 5 )=-2640.383
SECANT DATA
K( 1 )= 71    K( 2 )= 45    K( 3 )= 15    K( 4 )= 0     K( 5 )= 0
K( 6 )= 34    K( 7 )= 3     K( 8 )= 52    K( 9 )= 10    K( 10 )= 9    K( 11 )=
 13
```

TABLE 6.2 PSI/S3E NODE ARRAY

	MOLAR FLOW RATES - lb mole/hr									Press	Temp	Enthalpy	
NODE	H2	H2O	CH4	CO	CO2	O2	N2	FUEL	TOT	ATM	Deg-F	BTU/hr	NODE
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3241	0.3241	1.000	70	-3.0315E+04	1
2	0.0000	0.4377	0.0000	0.0000	0.0000	0.0648	1.0703	0.3241	1.8969	1.000	279	-6.0747E+04	2
3	0.0000	0.4377	0.0000	0.0000	0.0000	0.0648	1.0703	0.3241	1.8969	1.000	557	-5.6189E+04	3
4	0.7727	0.3131	0.0000	0.0699	0.2542	0.0000	1.0703	0.0000	2.4802	1.000	800	-5.5567E+04	4
5	0.7727	0.3131	0.0000	0.0699	0.2542	0.0000	1.0703	0.0000	2.4802	1.000	400	-6.3240E+04	5
6	0.8334	0.2524	0.0000	0.0091	0.3149	0.0000	1.0703	0.0000	2.4802	1.000	455	-6.3240E+04	6
7	0.3334	0.2524	0.0000	0.0091	0.3149	0.0000	1.0703	0.0000	1.9801	1.000	375	-6.7615E+04	7
8	0.3126	0.3044	0.0000	0.0612	0.2770	0.2429	1.9869	0.0000	3.1850	1.000	375	-6.2080E+04	8
9	0.0000	0.6170	0.0000	0.0000	0.3382	0.0561	1.9869	0.0000	2.9981	1.000	1935	-6.2080E+04	9
10	0.0000	0.6170	0.0000	0.0000	0.3382	0.0561	1.9869	0.0000	2.9981	1.000	1772	-6.6633E+04	10
11	0.0000	0.0000	0.0000	0.0000	0.0000	2.7719	10.4593	0.0000	13.2312	1.000	70	4.8714E+04	11
12	0.0000	0.0000	0.0000	0.0000	0.0000	6.7635	25.5207	0.0000	32.2842	1.000	250	1.5934E+05	12
13	0.0000	0.0000	0.0000	0.0000	0.0000	6.7635	25.5207	0.0000	32.2842	1.000	250	1.5934E+05	13
14	0.0000	0.0000	0.0000	0.0000	0.0000	6.7635	25.5207	0.0000	32.2842	1.000	375	1.8785E+05	14
15	0.0000	0.0000	0.0000	0.0000	0.0000	0.2837	1.0703	0.0000	1.3540	1.000	375	7.8783E+03	15
16	0.0000	0.4377	0.0000	0.0000	0.0000	0.0648	1.0703	0.0000	1.5728	1.000	375	-3.5465E+04	16
17	0.0000	0.4377	0.0000	0.0000	0.0000	0.0648	1.0703	0.0000	1.5728	1.000	796	-3.0432E+04	17
18	0.0000	0.0000	0.0000	0.0000	0.0000	6.4799	24.4504	0.0000	30.9303	1.000	375	1.7997E+05	18
19	0.0000	0.0000	0.0000	0.0000	0.0000	3.9916	15.0614	0.0000	19.0530	1.000	375	1.1086E+05	19
20	0.0000	0.0000	0.0000	0.0000	0.0000	2.4883	9.3890	0.0000	11.8773	1.000	375	6.9111E+04	20
21	0.0000	0.0000	0.0000	0.0000	0.0000	0.2429	0.9166	0.0000	1.1595	1.000	375	6.7471E+03	21
22	0.0000	0.0000	0.0000	0.0000	0.0000	2.2454	8.4724	0.0000	10.7177	1.000	375	6.2363E+04	22

TABLE 6.3

```
604162.WKS
THIS FILE IS FOR USE IN CONJUCTION WITH 604162.PRN FILSORT
COMMON PARAMETERS                          ####################################
PNET        5.000 KW      EFFICIENCY       LOWEST OVERALL VOLUME
FGROSS      7.250 KW      MECH       0.862
PARASITE    0.800 KW      INV        0.800 TOP 10 UNITS
                                           ####################################
TCELL     375.000 DEGF
BURN ENR    1.200
```

CASE	INDEPENDENT VARIABLES O2/C	UH	CELL VOLTS	AMBIENT TEMP	TATR	CURRENT DENSITY ASF	STACK AREA FT2	NUMBER CELLS	STACK VOLTS	STACK AMP	OXYGEN UTIL	H2O/C
203	0.150	0.650	0.580	105	800	142.176	87.919	63	36.540	199.047	0.855	1.763
207	0.150	0.650	0.580	125	800	142.176	87.919	63	36.540	199.047	0.855	1.763
199	0.150	0.650	0.580	90	800	142.176	87.919	63	36.540	199.047	0.855	1.763
195	0.150	0.650	0.580	70	800	142.176	87.919	63	36.540	199.047	0.855	1.763
267	0.150	0.700	0.580	125	800	138.534	90.231	64	37.120	193.947	0.864	1.900
264	0.150	0.700	0.580	105	800	138.534	90.231	64	37.120	193.947	0.864	1.900
261	0.150	0.700	0.580	90	800	138.534	90.231	64	37.120	193.947	0.864	1.900
258	0.150	0.700	0.580	70	800	138.534	90.231	64	37.120	193.947	0.864	1.900
307	0.100	0.600	0.580	70	800	139.172	89.817	64	37.120	194.841	0.894	1.684
311	0.100	0.600	0.580	90	800	139.172	89.817	64	37.120	194.841	0.894	1.684

TABLE 6.3 (CONTINUED)

CASE	EFFICIENCY OVERALL	STACK	FUEL PROC	HX AREA HX1	HX AREA HX2	FLOW RATES ACFM(NODE) ACFM4	ACFM9	ACFM11	ACFM12	Q(5) BTU/HR
203	0.225	0.463	0.704	0.623	6.900	33.970	65.235	100.779	273.549	2306.977
207	0.225	0.463	0.704	0.623	6.900	33.970	65.235	112.694	273.549	2306.977
199	0.225	0.463	0.704	0.623	6.900	33.970	65.235	92.940	273.549	2306.977
195	0.225	0.463	0.704	0.623	6.900	33.970	65.235	83.688	273.549	2306.977
267	0.242	0.463	0.758	0.739	6.757	32.986	55.915	112.694	273.549	2162.992
264	0.242	0.463	0.758	0.739	6.757	32.986	55.915	100.779	273.549	2162.992
261	0.242	0.463	0.758	0.739	6.757	32.986	55.915	92.940	273.549	2162.992
258	0.242	0.463	0.758	0.739	6.757	32.986	55.915	83.688	273.549	2162.992
307	0.208	0.463	0.650	0.917	6.485	35.033	78.095	83.688	273.549	2536.270
311	0.208	0.463	0.650	0.917	6.485	35.033	78.095	92.940	273.549	2536.270

STACK VOL FT3	REF VOL FT3	HX VOL FT3	INV VOL FT3	TOTAL VOL FT3
13.643	4.076	1.159	6.334	25.211
13.643	4.076	1.159	6.334	25.211
13.643	4.076	1.159	6.334	25.211
13.643	4.076	1.159	6.334	25.211
14.001	3.958	1.154	6.171	25.286
14.001	3.958	1.154	6.171	25.286
14.001	3.958	1.154	6.171	25.286
14.001	3.958	1.154	6.171	25.286
13.937	4.204	1.140	6.200	25.481
13.937	4.204	1.140	6.200	25.481

TABLE 6.4

604162.WKS
THIS FILE IS FOR USE IN CONJUCTION WITH 604162.PRN FILSORT

COMMON PARAMETERS				
PNET	5.000 KW	EFFICIENCY		HIGHEST OVERALL EFFICIENCY
PGROSS	7.250 KW	MECH	0.862	TOP 10 UNITS
PARASITE	0.800 KW	INV	0.800	

TCELL 375.000 DEGF
BURN ENR 1.200

CASE	INDEPENDENT VARIABLES O2/C	UH	CELL VOLTS	AMBIENT TEMP	TATR	CURRENT DENSITY ASF	STACK AREA FT2	NUMBER CELLS	STACK VOLTS	STACK AMP	OXYGEN UTIL	H2O/C
294	0.150	0.700	0.650	70	800	52.248	213.478	152	98.800	73.148	0.864	1.900
295	0.150	0.700	0.650	90	1200	50.226	222.072	159	103.350	70.317	0.863	1.893
299	0.150	0.700	0.650	105	1000	51.195	217.870	156	101.400	71.673	0.863	1.897
298	0.150	0.700	0.650	105	1200	50.226	222.072	159	103.350	70.317	0.863	1.893
303	0.150	0.700	0.650	125	800	52.248	213.478	152	98.800	73.148	0.864	1.900
297	0.150	0.700	0.650	90	800	52.248	213.478	152	98.800	73.148	0.864	1.900
301	0.150	0.700	0.650	125	1200	50.226	222.072	159	103.350	70.317	0.863	1.893
292	0.150	0.700	0.650	70	1200	50.226	222.072	159	103.350	70.317	0.863	1.893
296	0.150	0.700	0.650	90	1000	51.195	217.870	156	101.400	71.673	0.863	1.897
300	0.150	0.700	0.650	105	800	52.248	213.478	152	98.800	73.148	0.864	1.900
302	0.150	0.700	0.650	125	1000	51.195	217.870	156	101.400	71.673	0.863	1.897

CASE	EFFICIENCY OVERALL	STACK	FUEL PROC	HX AREA HX1	HX AREA HX2	FLOW RATES ACFM(NODE) ACFM4	ACFM9	ACFM11	ACFM12	Q(5) BTU/HR
294	0.271	0.519	0.758	0.660	6.027	29.434	49.893	66.905	218.690	1930.274
295	0.271	0.519	0.758	1.893	6.055	38.700	52.925	74.302	218.690	4099.203
299	0.271	0.519	0.758	1.054	6.065	34.075	52.044	80.569	218.690	3011.399
298	0.271	0.519	0.758	1.893	6.055	38.700	52.925	80.569	218.690	4099.203
303	0.271	0.519	0.758	0.660	6.027	29.434	49.893	90.094	218.690	1930.274
297	0.271	0.519	0.758	0.660	6.027	29.434	49.893	74.302	218.690	1930.274
301	0.271	0.519	0.758	1.893	6.055	38.700	52.925	90.094	218.690	4099.203
292	0.271	0.519	0.758	1.893	6.055	38.700	52.925	66.905	218.690	4099.203
296	0.271	0.519	0.758	1.054	6.065	34.075	52.044	74.302	218.690	3011.399
300	0.271	0.519	0.758	0.660	6.027	29.434	49.893	80.569	218.690	1930.274
302	0.271	0.519	0.758	1.054	6.065	34.075	52.044	90.094	218.690	3011.399

TABLE 6.5

604162.WKS
THIS FILE IS FOR USE IN CONJUCTION WITH 604162.FRN FILSORT

COMMON PARAMETERS					###################################
PNET	5.000 KW	EFFICIENCY			SMALLEST STACK AREA
PGROSS	7.250 KW	MECH	0.862		UNITS OVER 20% EFFICIENT
PARASITE	0.800 KW	INV	0.800		TOP 10 UNITS
					###################################

TCELL 375.000 DEGF
BURN ENR 1.200

CASE	INDEPENDENT VARIABLES O2/C	UH	CELL VOLTS	AMBIENT TEMP	TATR	CURRENT DENSITY ASF	STACK AREA FT2	NUMBER CELLS	STACK VOLTS	STACK AMP	OXYGEN UTIL	H2O/C
105	0.200	0.700	0.580	105	800	148.219	84.335	60	34.800	207.506	0.797	1.571
108	0.200	0.700	0.580	125	800	148.219	84.335	60	34.800	207.506	0.797	1.571
102	0.200	0.700	0.580	90	800	148.219	84.335	60	34.800	207.506	0.797	1.571
99	0.200	0.700	0.580	70	800	148.219	84.335	60	34.800	207.506	0.797	1.571
98	0.200	0.700	0.580	70	1000	145.902	85.674	61	35.380	204.263	0.798	1.576
104	0.200	0.700	0.580	105	1000	145.902	85.674	61	35.380	204.263	0.798	1.576
107	0.200	0.700	0.580	125	1000	145.902	85.674	61	35.380	204.263	0.798	1.576
101	0.200	0.700	0.580	90	1000	145.902	85.674	61	35.380	204.263	0.798	1.576
97	0.200	0.700	0.580	70	1200	143.797	86.928	62	35.960	201.316	0.798	1.581
100	0.200	0.700	0.580	90	1200	143.797	86.928	62	35.960	201.316	0.798	1.581

CASE	OVERALL	EFFICIENCY STACK	FUEL PROC	HX AREA HX1	HX AREA HX2	FLOW RATES ACFM(NODE) ACFM4	ACFM9	ACFM11	ACFM12	Q(5) BTU/HR
105	0.210	0.463	0.658	0.416	11.051	34.803	63.473	100.779	273.549	2262.317
108	0.210	0.463	0.658	0.416	11.051	34.803	63.473	112.694	273.549	2262.317
102	0.210	0.463	0.658	0.416	11.051	34.803	63.473	92.940	273.549	2262.317
99	0.210	0.463	0.658	0.416	11.051	34.803	63.473	83.688	273.549	2262.317
98	0.211	0.463	0.662	0.659	11.710	40.185	67.550	83.688	273.549	3482.008
104	0.211	0.463	0.662	0.659	11.710	40.185	67.550	100.779	273.549	3482.008
107	0.211	0.463	0.662	0.659	11.710	40.185	67.550	112.694	273.549	3482.008
101	0.211	0.463	0.662	0.659	11.710	40.185	67.550	92.940	273.549	3482.008
97	0.212	0.463	0.665	0.991	11.404	45.531	71.108	83.688	273.549	4710.567
100	0.212	0.463	0.665	0.991	11.404	45.531	71.108	92.940	273.549	4710.567

APPENDIX 1

ACID FUEL CELL LIBRARY - PAFCY
REVISED ATR MODULE

ACID FUEL CELL LIBRARY ADDITION

APPENDIX 1

ACID FUEL CELL LIBRARY ADDITION

During this reporting period a revised acid fuel cell library was written to accurately model the ERC fuel cell performance. The model was based on the fuel cell analysis in a report from Westinghouse Corp to DOE (NASA LeRC).

APPENDIX - PAFCY PROGRAMS

ANODE MODULE

```
950 GOSUB 600:A(6,OP)=A(6,IP)*(1-UO):A(2,OP)=2*A(6,IP)*UO:N=OP
    :GOSUB 400:GOSUB 3410:T(N)=TC:GOSUB 10
955 O2=FR(6,IP)*(1-UO)•(1-1/UO)*(1+FR(6,IP)*UO)
    •(-(1/UO+FR(6,IP))/FR(6,IP))
957 IF FR(2,IP)¼½0 THEN 960
958 H2O=(FR(2,IP)+FR(2,OP))/2:GOTO 965
960 H2O=(FR(2,IP)+2*FR(6,IP)*UO)*(1+FR(6,IP)*UO)
    •(-(1/UO+FR(6,IP))/FR(6,IP))*(1+2*FR(6,IP)*UO/FR(2,IP))
    •(FR(2,IP)/(2*FR(6,IP)*UO))
965 IF C1(6)¼=0 THEN GOSUB 1242
```

CATHODE MODULE

```
970 P(OP)=P(IP)-DP:RETURN
990 GOSUB 600:A(1,OP)=A(1,IP)*(1-UH):N=OP:GOSUB 400:GOSUB 3410
    :T(N)=TC:GOSUB 10
1000 H2=FR(1,IP)*(1-FR(1,IP)*UH)•(1/(FR(1,IP)*UH)-1)*(1-UH)
     •(1-1/UH)
1010 CC=-FR(4,IP)/(FR(1,IP)*UH)*LOG(1-FR(1,IP)*UH)
     :P(OP)=P(IP)-DP
1020 RETURN
```

PERFORMANCE MODULE

```
1200 REM PAFCY FOR ERC PERFORMANCE ANALYSIS      8/30/83
1205 IO!=C1(6)*(P(L4)*O2)•.8*(P(L4)*H2O)
     •.4377*EXP(-11974/(TC+460)):IO!=IO!*XIO
1210 EO=C1(1)+(TC+460)*(C1(2)*LOG(H2*SQR(P(L4)*O2)/H2O)
     -.0001389)
1215 IF TC=½350 THEN RES=.0006*XRES ELSE
     RES=.000473*EXP(6570/(TC+460)-8.111)*XRES
1216 VO1=C1(2)*(TC+460)*2:VO2=-VO1*LOG(IO!*CLC*C1(3))
1218 IF TC=½350 THEN VC1=0 ELSE
     VC1=C1(4)*P(L4)*CC*EXP(16543/(TC+460)-20.42)
1220 VC2=-VC1*LOG(CLA*C1(5))
1230 IF AF=0 THEN AF=136
1234 IF AF¼=0 THEN GOSUB 510:AF=.01
1235 V=EO-VO2-VC2:V=V-(VC1+VO1)*LOG(AF)-RES*AF
1236 DV=-(VC1+VO1)/AF-RES:EV=(V-VO)/DV:AF=AF-EV
     :IF ABS(V-VO)½.0001 THEN 1234
```

```
1240 RETURN
1242 C1(1)=1.261:C1(2)=2.3933E-05:C1(4)=.0782
    :C1(6)=216.17:XRES=1:XIO=1
1244 C1(3)=50!:'SA=5E5,CU=.1,CLC=MGM/CM2,IO=ASF CATHODE
1246 C1(5)=2.462:'SA=5.3e-2,CU=.1,IA0=5E5,
    ANODE ADJUSTED TO CLA=MGM/CM2 &ASF
1248 RETURN
```

CHECKOUT MAIN PROGRAM FOR PAFCY MODULES

```
4000 CLS:LOCATE 12,15
     :PRINT "PAFCXCO ACID FUEL CELL CHECKOUT 3/2/83"
4005 L2=1:L3=2:L4=3:L6=4:L7=5:L8=6

4007 'L2=AIR IN/L3=FUEL IN/L4=CATH IN/L6=COOL IN/L7=BURN IN
    /L8=ANOD IN

4010 UH=.7:UO=.4:VO=.6:TC=375:P=1:PN=3:EI=.8:EM=.95
     :PG=PN/(EI*EM):CLC=.5:CLA=.25:EO=.25
4020 PRINT"HYDROGEN UTILIZATION, UH=";UH;:INPUT AA
     :IF AA¼½0 THEN UH=AA
4030 PRINT"OXYGEN UTILIZATION, UO=";UO;:INPUT AA
     :IF AA¼½0 THEN UO=AA
4040 PRINT"CELL VOLTAGE, VO=";VO;" VOLTS";:INPUT AA
     :IF AA¼½0 THEN VO=AA
4050 PRINT"CELL TEMPERATURE, TC=";TC;" DEGF";:INPUT AA
     :IF AA¼½0 THEN TC=AA
4055 PRINT"PRESSURE, P=";P;" ATM";:INPUT AA:IF AA¼½0 THEN P=AA
4060 PRINT"CATHODE CAT LOAD, CLC=";CLC;" MG/CM2";:INPUT AA
     :IF AA¼½0 THEN CLC=AA
4070 PRINT"ANODE CAT LOAD, CLA=";CLA;" MG/CM2";:INPUT AA
     :IF AA¼½0 THEN CLA=AA
4075 PRINT TAB(20)"CELL PERFORMANCE FIT COEFFICIENTS FOR ERC"
4080 A(8,L3)=3413*PG/(290851.8*EO)
4100 PRINT "ANODE ";
4110 N=L8:GOSUB 410:A(1,N)=2.8667:A(2,N)=.4333:A(4,N)=.1333
     :A(5,N)=.8667
4120 T(N)=TC :P(N)=P:FOR J=1 TO 5:A(J,N)=A(8,L3)*A(J,N):NEXT J
4130 GOSUB 400:GOSUB 3410:GOSUB 10:T(N)=500:GOSUB 550
     :GOSUB 3410:T(N)=TC
4140 IP=L8:OP=7: GOSUB 990 'ANOD
4150 PRINT "CATHODE ";
4160 N=L4:GOSUB 410:A(6,N)=.04112*PG/(2*VO*UO)
     :A(7,N)=3.733*A(6,N):A(2,N)=.01
4170 T(N)=TC :P(N)=P:GOSUB 400:GOSUB 3410:GOSUB 10
4180 IP=L4:OP=4: GOSUB 950 'CATH
4190 PRINT "PERF"
4192 CLS:PRINT"PERFORMANCE TESTING"
4194 VO(1)=.55:VO(2)=.5750001:VO(3)=.63:VO(4)=.68:VO(5)=.77
4196 INPUT "INPUT XIO AND XRES";XIO,XRES
4198 FOR JL= 1 TO 5:VO=VO(JL)
4200 GOSUB 1200 'PERF
4202 PRINT "VO=";VO,"AF=";AF,"XIO=";XIO,"XRES=",XRES:GOSUB 6000
     :STOP:NEXT JL
4204 GOSUB 6000:STOP:GOTO 4196
4210 LPRINT "PERFORMANCE OF ";C1$
4220 LPRINT "CELL VOLTS, VO";TAB(40) VO;" VOLTS"
4230 LPRINT "CURRENT DENSITY, AF";TAB(40) AF;" AMP/FT2"
4240 LPRINT "CELL TEMPERATURE, TC";TAB(40) TC;" DEGF"
4250 LPRINT "CELL PRESSURE, P";TAB(40) P;" ATM"
4260 LPRINT "HYDROGEN UTILIZATION, UH";TAB(40) UH
4270 LPRINT "OXYGEN UTILIZATION, UO";TAB(40) UO
```

```
4280 LPRINT "CATHODE CAT. LOAD., CL";TAB(40) CL;"MG/CM2"
4290 LPRINT "CELL RESISTANCE, CR";TAB(40) CR
4292 LPRINT TAB(20) "CELL PERFORMANCE COEFFICENTS"
4300 LPRINT "C1(1)";TAB(40) C1(1)
4310 LPRINT "C1(2)";TAB(40) C1(2): LPRINT" "
4312 LPRINT "GROSS POWER, PG=";TAB(40) PG;" KW"
4314 LPRINT "COOLANT HEAT LOAD, QC=";TAB(40)
    ;H(1)+H(3)-H(2)-H(4)-PG*3413;" BTU/HR"
4320 AR=40000!/(V0*AF): LPRINT "ACTIVE CELL AREA FOR 40 KW"
    ;TAB(40) AR;" FT2"
4330 LPRINT "CELL STACK COST AT $20/FT2";TAB(39)"$";20!*AR
    :LPRINT:LPRINT
4340 GOSUB 1800
4345 LPRINT"H2=";H2,"O2=";O2,"H20=";H20,"I0!=";I0!,"E0=";E0
4350 END
```

```
                 PAFCXCO ACID FUEL CELL CHECKOUT 3/2/83
HYDROGEN UTILIZATION, UH= .7 ?
OXYGEN UTILIZATION, UO= .4 ?
CELL VOLTAGE, VO= .6  VOLTS?
CELL TEMPERATURE, TC= 375  DEGF?
PRESSURE, P= 1  ATM?
CATHODE CAT LOAD, CLC= .5  MG/CM2?
ANODE CAT LOAD, CLA= .25  MG/CM2?
                     CELL PERFORMANCE FIT COEFFICIENTS FOR ERC
ANODE



PERFORMANCE TESTING
INPUT XIO AND XRES? 1,1
VO= .55       AF= 141.9743  XIO= 1       XRES=        1
VO=  5750001  AF= 114.5848  XIO= 1       XRES=        1
VO= .63       AF= 62.8859   XIO= 1       XRES=        1
VO= .68       AF= 29.64587  XIO= 1       XRES=        1
VO= .77       AF= 4.546327  XIO= 1       XRES=        1
INPUT XIO AND XRES?
```

```
:RC PERFORMANCE DIAGNOSTICS
:(L4)= 1          O2= .1595474   H2= .5553766   CC= 2.869056E-02          TC= 375
:1( 1 )= 1.261                   C1( 2 )= 2.3933E-05          C1( 3 )= 50   C1( 4 )=
.(  '2            C1( 5 )= 2.462               C1( 6 )= 216.17              IO!=
 9.175555E-06                    EO= 1.168189   RES= .0006
/O1= 3.996811E-02                VO2= .3349365               VC1= 0         VC2= 0
:LA= .25          CLC= .5
/= .7700831       AF= 4.546327   DV=-9.408408E-03            EV=-8.831342E-03
```

PSI/S3E NODE ARRAY

MOLAR FLOW RATES - lb mole/hr

NODE	H2	H2O	CH4	CO	CO2	O2	N2	FUEL	TOT	Press ATM	Temp Deg-F	Enthalpy BTU/hr	NODE
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	1
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1853	0.0000	0.0000	0	0.0000E+00	2
3	0.0000	0.0100	0.0000	0.0000	0.0000	0.3382	1.2623	0.0000	1.6105	1.0000	375	8.3520E+03	3
4	0.0000	0.2705	0.0000	0.0000	0.0000	0.2029	1.2623	0.0000	1.7358	1.0000	375	-1.7477E+04	4
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	5
6	0.5390	0.0725	0.0000	0.0169	0.1684	0.0000	0.0000	0.0000	0.7967	1.0000	375	-3.1795E+04	6
7	0.1617	0.0725	0.0000	0.0169	0.1684	0.0000	0.0000	0.0000	0.4194	1.0000	375	-3.4087E+04	7
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	8
9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000E+00	9

```
        POWER SYSTEM PROGRAM OUTPUT AT NODE  6
SPECIES     LB-MOL/HR          MOL FRAC
               0.80             1.0000
H2             0.54             0.6765
H2O            0.07             0.0909
CH4            0.00             0.0000
CO             0.02             0.0212
CO2            0.17             0.2114
O2             0.00             0.0000
N2             0.00             0.0000
CH3OH          0.00             0.0000
        THERMAL OUTPUT
H= -31795.43  BTU/HR, P=  1  ATM, T=  375  DEG F
Break in 109
O
```

ATR MODULE REVISED FOR METHANOL FUEL

ATR MODULE REVISED FOR METHANOL FUEL

```
610 T=T(OP):GOSUB 600:A(7,OP)=A(7,IP):A(8,OP)=0:A(6,OP)=0:LL=0
615 IF T=0 THEN T(OP)=T(IP) ELSE T(OP)=T
620 N=IP:GOSUB 300:NH=1:GOSUB 10:N=OP
630 GOSUB 390:IF LL<>0 THEN 650 ELSE LL=1
640 A(8,N)=.01*C
650 A(1,N)=H/2-O+2*C-3*A(8,N):A(2,N)=O-2*C+A(8,N):A(5,N)=C-A(8,N):A(4,N)=0
660 GOSUB 550:GOSUB 400
670 FM=A(5,N)*(A(3,N)*P(N)/A(0,N))^3/(A(2,N)*A(0,N)*P(N)*R)
680 X=A(8,N):Y=A(8,N)-FM:Y0=0:J5=1:EE=.001:GOSUB 440
690 A(8,N)=X:IF  K(J5)<>0  THEN 650
700 GOSUB 400:GOSUB 3410:GOSUB 10
710 X=T(OP):Y=H(OP):Y0=H(IP):J5=2:EE=.01:GOSUB 440
720 T(OP)=X:IF K(J5)<>0 THEN 630
730 P(OP)=P(IP)-DP:RETURN
```

APPENDIX 2

OPERATING INSTRUCTIONS AND CODE LISTINGS
CONFIGURATION GO41G

APPENDIX 2

SYSTEM SIMULATION & CODES DEVELOPED

APPROACH FOLLOWED IN THE MODELING PROCESS

Having defined the nature of the problem including its constraints, we will now review the general approach we followed in developing and analyzing the systems.

1. DEVELOP A TRIAL CONFIGURATION

The first step is to select the technologies to be employed and to synthesize a trial configuration. During the course of the program we developed and analyzed four systems:

	STACK COOLING	WATER SEPARATION	FUEL PROCESSOR
D	TWO PHASE	CONDENSING	CATALYTIC STEAM
E	AIR	CONDENSING	CATALYTIC STEAM
F	AIR	ADIABATIC	PARTIAL OXIDATION +SHIFT
G	AIR	NONE	AUTOTHERMAL + SHIFT

2. FLOWSHEET MODEL SYNTHESIS

With the flowsheet developed in step 1, we next proceeded to develop a flowsheet simulator model with the PSI/S3E code. This consists of developing a main program to access the relevant component models in the PSI/S3E library.

3. PRELIMINARY DESIGN POINT ANALYSIS

With the flowsheet simulation code developed, the next step is to obtain a preliminary estimate of power plant performance at a given set of operating conditions. This type of analysis is useful in modifying the system configuration. The first configuration chosen is seldom successful. We may then explore the power plant's performance over a wider range of parameters. This serves to define the allowable range of design conditions we can employ in optimization studies.

For example, our preliminary evaluation of the partial oxidation approach, configuration F, showed large amounts of CO present at the anode inlet. We modified the configuration to include of a shift converter. This modification did not effectively reduce the anode inlet CO concentration. We next developed a model of an adiabatic water transport system to increase the flow of water to the shift converter inlet. While this improved the efficiency somewhat, the improvement was not sufficient to progress to the next step; design optimiztion.

4. OPTIMIZATION

The power plant, having shown reasonable performance in the

preceeding steps was next subjected to an optimization process. The optimization process we employed was somewhat of a "brute force" approach. We found that it was fairly tractable for use in microcomputer based systems. While we have developed and used an optimization routine which exists in the PSI/S3E code it was felt that a more straightforward approach would be faster.

The approach involves running the flowsheet simulation code over a range of parameter values. We record the output (automatically) of each case as it is completed in a data file. Next we load the data file into a spreadsheet program (LOTUS) and sort the case data to determine the systems which yielded the optimum efficiency, weight and volume values.

The parametric study of a configuration's response to design and operating condition variation was performed by varying the input quantities shown in Table 1.

TABLE 1 - OPTIMIZATION PARAMETERS

PARAMETER	RANGE
O2/C ratio (PSI)	0.2 - 0.15 - 0.1
Hydrogen utilization (UH)	0.6 - 0.65 - 0.7
Cell Volts (VO)	0.58- 0.60 - 0.625 - 0.65
Ambient Temperature T(L2)	70 - 90 - 105 - 125
ATR exit Temperature TATR	1400-1200 - 1000 - 800

In order to speed the flowsheet simulation operations the complete simulation code was compiled with the IBM/PC Basic Compiler (BASCOM). While analyzing the flowsheet in the interpreted basic language, with complete graphics diagnostics we found that it took 10 to 15 minutes per case. With the graphics removed and with the input process automated, the per case execution time is reduced to about 30 sec.

In the case of the G configuration, the autothermal reforming case, we analyzed a total of 576 cases. This was accomplished by running the computer overnight and processing the complete output data file the next day.

The data file generated contained both the case input and output information from the simulation code. Sorting the cases in the spreadsheet format was accomplished with the simple expedient of using the sort utility of that code.

SYSTEM DESCRIPTION

Methanol fuel enters the power plant at node 1 where it is mixed with heated, moist cathode exhaust from node 17. The output of this mixer, node 2, contains cathode exhaust and vaporized methanol. It is fed to a heat exchanger (HX1) which serves to preheat the mixture prior to its entry into the ATR at node 3. Preheat is provided by hot burner exhaust at node 9. The reformed methanol mixture leaves the ATR at node 4 and enters a heat exchanger (HX2) which serves to cool the mixture prior to its entry into the shift converter. As previously mentioned, HX2 also serves to preheat the cathode exhaust.

In the analysis we attempt to cool the mixture to a temperature as close to cell exit temperature as possible; using a heat exchanger effectiveness commensurate with the ATR exit temperature. It is obviously not possible to reach fuel cell exit temperatures at node 5. We assume that heat can be dumped at node 5 so that the inlet temperature to the shift converter is about 400 deg F. The shift effluent is fed directly to the anode, and the effluent from the anode at node 7 then proceeds to the burner via a mixer. The burner effluent is used in HX1 to preheat the ATR inlet stream 3.

The air loop starts with the inlet at node 11. We then proceed through a mixer. In the mixer, a portion of the cell cooler exhaust is recycled to preheat the cooler inlet stream to 250 deg-F. In air cooled systems this is an appropriate cooler air inlet temperature. Proceeding through the cooler, the effluent at node 14 is split into cathode feed at node 15, recycle at node 19, and to burner air at node 21. The remaining air is exhausted at node 22.

The numbers shown in Fig 1 represent intercomponent stream numbers or "nodes". The accompanying Table 2 shows the thermodynamic properties existant at those nodes when the configuration was evaluated during the preliminary analysis step.

CONFIGURATION G041G CODES

At this point we will summarize the codes developed as part of this effort and describe how they may be used.

G041G.S3E Series of codes

This code is presents a detailed analysis of the G041G configuration. It includes extensive diagnostics and graphic displays. It is designed to assist the analyst in obtaining a clear picture of the operation of the system. It also may be used for the diagnosis of problems which may arise when attempting to operate the system outside the range of conditions described in the parametric sensitivity studies conducted. The code is designed to run in the PSI/S3E environment.

Along with the conventional node arrays and databloc output, the code generates three random access data files: SYS1.DAT, SYS2.DAT

and SYS3.DAT. These files will store summary databloc information from successive runs. The node array information is saved for a single run in the G041G.DAT data file. We have provided a supporting code READSYS.BAS which may be used to access the random access files previously noted. Examples of the type of data obtainable with these codes is shown in the accompanying figures. Summarizing, the G041G codes are:

G041G.S3E - main program, SYSM module, runtime library
G041G.DAT - node array for a single run
SYS(1-3).DAT - random access files for successive runs

G041G2 Series of codes

A parametric study of the G041G system configuration was run over a range of operating conditions. We will briefly describe the codes and their functions here to assist the analyst in their use. The codes we will describe are to be found on three separate diskettes.

G041G2 PARAMETRICS DISKETTE 1

G041G2.BAS - This code is similar to the G041G.S3E code in that is used to analyze the G041G configuration. However, it is designed to run at high speed and in a compiled form. The G041G2.BAS code is the source code for the compiled code G041G2.EXE. In the G041G2.BAS code most diagnostics and graphics have been eliminated along with their supporting modules. In addition, a separate SYSM module was developed so that the code will run over a range of five variables. In the parametric study performed, we varied the following:

Parameter	Range
O2/C ratio (PSI)	0.2 - 0.15 - 0.1
Hydrogen utilization (UH) from	0.6 - 0.65 - 0.7
Cell Volts (VO)	0.58- 0.60 - 0.625 - 0.65
Ambient Temperature T(L2)	70 - 90 - 105 - 125
ATR exit Temperature TATR	1400-1200 - 1000 - 800

In a nested form this yields 576 cases. Of this number, 433 cases were successfully resolved. Failures are attributable principally to impossible operating conditions. Some code errors may have resulted which caused failures.

In addition to the modified SYSM module, the file structure of the random access files was changed. This was done to permit the storage of several flows which are important in sizing equipment. The random access files generated are three in number and are designated:

SYS1G2.DAT
SYS2G2.DAT
SYS3G2.DAT

These files are used in conjuntion with several other codes which are found on diskette 3.

In future studies it may be desireable to extend the range of the variables chosen for the study or to look at a different set of parameters. This is readily accomplished by editing the SYSM module of the G041G2.BAS code and recompiling.

G041G2 PARAMETRICS DISKETTE 2

G041G2.EXE - This is the compiled version of G041G2.BAS described above. The code was developed with the IBM BASCOM compiler. The function of this code is to generate the three random access files SYS1G2.DAT, SYS2G2.DAT and SYS3G2.DAT. These data files contain all of the system data generated over the successfule runs of the compiled code. While each case takes about one minute of execution time, substantially shorter than the uncompiled version, the entire parametric study takes several hours. We have included this code on a separate diskette because the files it generates are quite large. Moreover the compilation of the code using the BASCOM switches (/o/x/d) result in an object code of about 120K.

READSYS.BAS - This code is used to read the results of individual runs which are stored in the three random access files noted above. Using this code, the analyst can call the results of any single case from the random access file.

WRITESYS.BAS - While it may be of interest to examine single cases from the random access files, the primary purpose of the parametric study was to analyze a large volume of data. For this reason, the WRITESYS.BAS program was developed. The code reads all of the data from the random access files created by the compiled code and creates a PRN file which is readable by a spreadsheet code. The PRN file is G041G2.PRN.

G041G2 PARAMETRICS DISKETTE 3

G041G2.WKS - This is a LOTUS 1 2 3 spreadsheet code. It is designed to be used in conjuction with the PRN file created by WRITESYS.BAS. In the results section we have used the sort instruction to determine the optimum design condition for the G041G configuration.

In order to develop the data for a parametric study using the spreadsheet code, the analyst should follow the following steps:

a. Using the G041G.S3E code, run the program at the extrema of the data range to be investigated. This will determine whether the system can be operated over the desired range. If errors arise, the analyst will be able to determine the nature of the errors using this code. This type of study will serve to set the allowable range of operating conditions for the parametric study.

b. Modify the G041G2.BAS code to incorporate the range of operating or design conditions desired. This is accomplished by editing the SYSM module only.

c. Once the G041G2.BAS code is modified, compile the code. This will generate two codes: G041G2.EXE and G041G2.OBJ. The latter may be erased. We suggest the use of the /o option in the compiler as this will include the required library into the compiled code. The use of the /x option during compilation is required as there are numerous error traps in the source code and the /x option will allow these to operate properly during the execution. Finally we advocate the use of the /d option during compilation. This will include debugging at compilation time and will point up code errors which might not otherwise show up.

d. When the G041G2.EXE code is executed the three random access data files will be generated. Again these are: SYS1G2.DAT, SYS2G2.DAT and SYS3G2.DAT. These files are the primary source of information for the following studies. If the analyst desires to modify the parameters normally carried in these files it will be necessary to modify not only the Main program in G041G2.BAS but the auxiliary programs READSYS.BAS and WRITESYS.BAS as well.

e. When the three random access files are created, the next step is to create the PRN file for the Lotus spreadsheet program. Prior to this it will be useful to scan the results with the READSYS.BAS code. When this preliminary review is performed the WRITESYS.BAS code may be run. The WRITESYS.BAS code will automatically generate the G041G2.PRN data file.

f. When the G041G2.PRN file has been created, the analyst enters the LOTUS 1 2 3 spreadsheet code. First the analyst loads the program G041G2.WKS program. Next locating the cursor at the first data location, erase the existing data resident in the spreadsheet. When the existing data has been cleared, the G041G2.PRN data may be loaded using the IMPORT command associated with file handling. When these instructions have been completed the analyst may use the DATA or GRAPH commands to further analyze the cases developed during the course of this program.

PARAMETRIC STUDY RESULTS

The major findings of the parametric study results are shown in Table 1. This table was created with the G041G2.WKS code. As shown in the table, of the 433 successful cases run, the optimum design occurs at the following conditions:

O2/C	0.15
UH	0.65
VO	0.58 volts
T(L2)	70-125 deg F
TATR	800 deg F

The optimum condition is determined as the lowest volume case. The system data is included in Table 1.

In Table 2 we show those cases having the highest overall efficiency. From the table we note that this efficiency is 27.1%. Because the stack areas of these systems were very large, due to the high cell voltage, we examined the case of powerplants having efficiencies above 20% and having the smallest stack areas. Note that these all occur at cell voltages of 0.58 as one would expect. These results are shown in Table 3.

It is also interesting to note that most of the cases of both low volume and high efficiency occured at the lower values of ATR exit temperature. In fact of the ten cases examined for lowest volume no ATR temperature other than 800 deg F was noted. As noted in table 1, in order to obtain a small power plant, the cell voltage must be a minimum.

SYSSM MODULE G041G

```
3000 REM SYSM MODULE (27) EXTERNALLY ASSIGN L2 - L7 ,CH3OH FUEL
3010 DATA 5,.800,.58,.6,.6,.8,.25,1.2,1.3,1,4,70,70,375,375,375,35,1,345,1,.41,0
,500,.15,62.4,000,.34,30,2,2,5,.2,1400
3020 READ PN,PP,VO,UH,UO,EI,EO,BE,PHI,XN,XM,T(L2),T(L3),TC,T(L6),T(L7),DE,P,TB,N
B!,NT!,NJ!,T(IA),EF(7),RO,M,PD,DT,NC!,ND!,A(6,N6),PSI,TATR
3021 PRINT"ANY UPDATES,YES OR NO"
3022 U$=INKEY$:IF U$="" THEN 3022 ELSE IF LEFT$(U$,1)="N" OR LEFT$(U$,1) ="n" TH
EN 3038
3024 AA=0:PRINT "INPUT ATR O2/C, DEFAULT =";PSI;:INPUT AA:IF AA<>0 THEN PSI=AA
3025 AA=0:PRINT "INPUT U2 UTILIZATION DEFAULT =";UH;:INPUT AA:IF AA<>0 THEN UH=A
A
3026 AA=0:PRINT "INPUT CELL VOLTS DEFAULT =";VO;:INPUT AA:IF AA<>0 THEN VO=AA
3027 AA=0:PRINT "INPUT AIR INLET TEMP, DEFAULT =";T(L2);:INPUT AA:IF AA<>0 THEN
T(L2)=AA
3028 AA=0:PRINT "INPUT ATR EXIT TEMP, DEFAULT =";TATR;:INPUT AA:IF AA<>0 THEN TA
TR=AA
3038 FOR N=1 TO 25:P(N)=1:NEXT N
3039 GOSUB 1242
3040 EM=PN/(PN+PP):PG=PN/(EM*EI):HR=3957.2/EO
3045 ES=VO/1.2527:EF=1.0726*UH:EO=EF*EM*EI*ES
3050 A(8,L3)=.01174*PN/EO:A(1,L8)=.04112*PG/(VO*UH):REFH2=A(1,L8)
3055 N=L3:GOSUB 400:GOSUB 3410:LQ=1:GOSUB 10 '    DEF L3
3060 UO=A(1,L8)*UH/(A(1,L8)*UH+2*PSI*A(8,L3))
3065 A(6,L4)=A(1,L8)*UH/(2*UO):A(7,L4)=3.7733*A(6,L4):N=L4:GOSUB 400:GOSUB 3410:
GOSUB 10  '   DEF L4
3070 A(6,L7)=BE*(1.5*A(8,L3)-A(1,L8)*UH/2-PSI*A(8,L3)):A(7,L7)=3.7733*A(6,L7):N=
L7:GOSUB 400:GOSUB 3410:GOSUB 10'    DEF L7
3075 PHI=A(1,L8)*UH/A(8,L3)
3080 N=L6:A(6,N)=.2095:A(7,N)=1-A(6,N):GOSUB 400:GOSUB 3410:NH=3:GOSUB 10 '  DEF
 L6
3085 QS=3413*PG*(1-ES)/ES
3090 A(0,N)=QS/(CP*(T(N)-250)):GOSUB 3420:GOSUB 10
3092 FOR J=15 TO 22:T(J)=T(N):NEXT
3095 IP=L6:FOR OP=12 TO 13:N=OP:GOSUB 600:T(N)=250:GOSUB 10:NEXT 'DEF 12,13
3100 I9=L6:J9=L4:K9=18:F=A(0,J9)/A(0,I9):GOSUB 880 ' DEF 18
3105 A(0,L2)=A(0,12)*(T(19)-T(12))/(T(19)-T(L2)):N=L2:FR(6,N)=.2095:FR(7,N)=1-.2
095:GOSUB 3420:GOSUB 10 '   DEF L2
3110 A(0,19)=A(0,12)-A(0,L2):F=A(0,19)/A(0,18):I9=18:J9=19:K9=20:GOSUB 880 '   DE
F 19,20
3115 I9=20:J9=21:K9=22:F=A(6,21)/A(6,20):GOSUB 880 'DEF 21,22
3120 IP=15:OP=16:GOSUB 600:GOSUB 950 'DEF 16
3150 RETURN
```

SYSM MODULE GO41G (continued)

```
3200 REM OUTPUT PRINT SYSTEM DATA BLOCK
3205 LPRINT CHR$(27);"@";CHR$(27);"E";TAB(30);CHR$(14);"SYSTEM DATA BLOCK":LPRIN
T CHR$(27);"@"
3210 LPRINT "PARAMETRIC STUDY PARAMETERS":LPRINT"":LPRINT "ATR O2/C= ";PSI
3215 LPRINT "HYDROGEN UTILIZATION ";UH
3220 LPRINT "CELL VOLTS =";VO
3225 LPRINT "AIR INLET TEMP=";T(L2)
3230 LPRINT "ATR EXIT TEMP, DEFAULT =";TATR
3235 LPRINT "POWER (KW)"
3240 LPRINT TAB(10) "NET=";PN,"GROSS=";PG,"PARASITE=";PP
3245 LPRINT TAB(10)  "CELL VOLTAGE=";VO,"CURRENT DENSITY=";AF;"  ASF"
3250 ATOT=PG*1000/(VO*AF):NC=ATOT/1.4:VSTACK=NC*VO:AMP=1.4*AF
3255 LPRINT TAB(10)"FUEL CELL AREA=";ATOT;" SQFT"
3260 LPRINT TAB(10)"NUMBER OF CELLS @ 1.4 FT2=";NC
3265 LPRINT TAB(10)"STACK VOLTS=";VSTACK
3270 LPRINT TAB(10)"STACK CURRENT=";AMP";AMP":LPRINT
3275 LPRINT TAB(10)"CELL TEMPERATURE=";TC;"DEG F"
3280 LPRINT "UTILIZATIONS"
3285 LPRINT TAB(10) "HYDROGEN=";UH,"AIR(STACK)=";UO
3290 LPRINT TAB(10)"BURNER ENRICHMENT=";BE:LPRINT
3295 LPRINT"ATR FUEL PROCESSOR OUTPUT"
3300 LPRINT"WATER TO FUEL RATIO=";PHI,"O2/FUEL RATIO=";PSI
3305 LPRINT "EFFICIENCY"
3310 LPRINT TAB(10)"OVERALL=";EO
3315 LPRINT TAB(10) "FUEL CELL=";ES,"MECHANICAL=";EM
3320 LPRINT TAB(10)"INVERTER=";EI,"FUEL PROCESSOR=";EF:LPRINT
3325 LPRINT "HX DATA NTU"
3326 LPRINT TAB(10) "HX-1=";N!(1),"HX-2=";N!(2)
3327 'ASSUMED U=10
3328 AREA(1)=N!(1)*CS(1)/10:AREA(2)=N!(2)*CS(2)/10
3335 LPRINT "HEAT EXCHANGER AREA"
3336 LPRINT TAB(20)"HX 1 AREA=";AREA(1);" FT2","HX 2 AREA=";AREA(2);" FT2"
3340 LPRINT "QBAL DATA"
3345 FOR J=1 TO 40:IF Q(J)=0 THEN 3355
3350 LPRINT TAB(10)"Q(";J;")=";Q(J),;
3355 NEXT:LPRINT" "
3360 LPRINT "SECANT DATA"
3365 FOR J=1 TO 5:LPRINT "K(";J;")=";SS(J),;:NEXT:LPRINT""
3370 FOR J=6 TO 11:LPRINT "K(";J;")=";SS(J),;
3375 NEXT:LPRINT" ":RETURN
```

MAIN PROGRAM CONFIGURATION GO41G

```
4000 '===============CONFIGURATION G041G.SSE MAIN 1/7/83====
4005 '===============SYSM SETUP==============================='
4010 L2=11:L3=1:L4=15:L6=14:L7=21:L8=6:KEY OFF
4015 '====================ACCESS SYSM====================
4020 GOSUB 3000
4022 PRINT"TO ACCESS DATA TYPE GOTO 4240":STOP:GOTO 4025
4023 GOSUB 3021
4025 CLS:LOCATE 10,10:PRINT"RETURN FROM SYSM":IC=5:GOSUB 4285
4030 IP=16:OP=17:GOSUB 600
4035 '==============ATR ANALYSIS================================
4040 CLS:LOCATE 1,1:PRINT"ATR ANALYSIS";
4045 EF(1)=.7:T(4)=TATR:N=17:T(N)=T(16)+EF(1)*(T(4)-T(16)):GOSUB 10
4050 T(4)=TATR:T(3)=T(4):GOSUB 4465:N!(2)=5
4055 '==============HX 2 APPROXIMATION==========================
4057 CLS:IP=4:OP=5:GOSUB 600:N=5:T(N)=800:GOSUB 10
4060 LOCATE 1,1:PRINT "HX2 ANALYSIS";:GOSUB 5000
4065 N!=N!(2):I7=4:J7=5:I8=16:J8=17:J5=6:IC=1:A5=J5:GOSUB 1300:IF K(6)<>0 THEN 4
060
4070 IF T(5)<400 AND T(5)>350 THEN 4085
4075 IP=5:OP=24:GOSUB 600:IP=5:OP=0:T(OP)=400:GOSUB 900:IP=0:OP=5:GOSUB 600
4080 IC=5:NXN=208:MYM=52:GOSUB 4285
4082 DELT=T(24)-TC
4085 GOSUB 4580
4090 '=====================FUEL CELL ANALYSIS==============
4095 GOSUB 4590
4100 '==============MIX2========================================
4105 LOCATE 1,1:PRINT"MIX2 ANALYSIS";
4110 I9=7:J9=21:K9=8:GOSUB 910
4115 '==============BURN========================================
4120 LOCATE 1,1:PRINT"BURNER ANALYSIS";
4125 GOSUB 4450
4130 '==============HX1=========================================
4135 GOSUB 4540
4140 '==============FUEL CLOSURE=================================
4145 CLS:LOCATE 10,10:PRINT"FUEL CLOSURE ANALYSIS"
4150 GOSUB 6000:J5=7:X=A(8,L3):Y=A(1,6):YO=REFH2:EE=.03:GOSUB 440:A(8,L3)=X:IF K
(J5)=0 THEN 4255 ELSE GOSUB 5000
4155 EO=.01174*PN/A(8,L3):EF=EO/(ES*EI*EM)
```

MAIN PROGRAM G041G (continued)

```
4160 LOCATE 25,1:PRINT "HIT ANY KEY TO CONTINUE";
4165 IF INKEY$=""THEN 4165
4170 '==============SYSM RECALL==================================
4175 TT=T(17):LOCATE 1,1:PRINT "SYSM RECALL";:GOSUB 3055:N!=N!(2):NXN=0:MYM=0:IC
=5:GOSUB 4285
4180 IP=16:OP=17:GOSUB 600:N=17:T(N)=TT:GOSUB 10
4185 CLS:GOSUB 4425' BURNER
4190 CLS:GOSUB 4455' ATR
4195 CLS:IP=4:OP=5:GOSUB 600:T(5)=T(24):GOSUB 10:GOSUB 4490' HX2
4200 CLS:GOSUB 4540' HX1
4205 CLS:GOSUB 4580' SHIFT
4210 CLS:GOSUB 4590' FUEL CELL
4215 GOTO 4140
4220 '==============END FUEL CLOSURE LOOP========================
4225 '            START MAIN PROGRAM SUBROUTINES
4230 '=====================DISCOPS ACCESS==================
4235 PRINT"SAVE G041D.DAT":STOP:GOSUB 6000:STOP
4240 PRINT"GET G041D.DAT":STOP:GOSUB 6040:STOP
4245 I1=8:I2=9:I3=4:IA=27:I4=27  'NODE 27 IS A DUMMY OF NODE 11
4250 GOSUB 4290:CLS:A5=2:IC=1:NT!=1
4255 '=====================ANALYSIS COMPLETE===============
4260 IC=5:NXN=0:MYM=0:GOSUB 4290
4265 LOCATE 25,1:PRINT"ANALYSIS COMPLETE, HIT ANY KEY TO CONTINUE"
4270 CLS:LOCATE 10,20:PRINT"HARDCOPY FOLLOWS"
4275 GOSUB 4630:GOSUB 3200:GOSUB 1800
4280 AN$="":CLS:LOCATE 10,10:PRINT"DO YOU WISH TO RUN ANOTHER CASE, Y OR N"
4282 AN$=INKEY$:IF AN$="" THEN 4282 ELSE IF AN$="Y" THEN 4023
4283 END
4285 '=====================CONFIGURATION SCREEN============
4290 IF IC<>5 THEN RETURN ELSE CLS:SCREEN 1,1,0,0:WIDTH 80:KEY OFF:DEF SEG=&HB80
0:BLOAD"G041G.PIC",0:IF NXN<>0 AND MYM<>0 THEN PAINT(NXN,MYM),1 ELSE GOSUB 4360
4295 GOSUB 4370
4300 LOCATE 5,19:PRINT XZ$(4);:LOCATE 5,30:PRINT XZ$(5);:LOCATE 5,41:PRINT XZ$(6
)
4305 LOCATE 5,55:PRINT XZ$(7);:LOCATE 4,69:PRINT XZ$(9);
4310 LOCATE 9,34:PRINT XZ$(16);:LOCATE 9,53:PRINT XZ$(15);
4315 LOCATE 11,14:PRINT XZ$(3);:LOCATE 12,35:PRINT XZ$(13);
4320 LOCATE 12,53:PRINT XZ$(14);:LOCATE 12,71:PRINT XZ$(8);
4325 LOCATE 13,19:PRINT XZ$(17);:LOCATE 14,55:PRINT XZ$(18);
4330 LOCATE 14,68:PRINT XZ$(21);:LOCATE 15,38:PRINT XZ$(12)
```

MAIN PROGRAM GO41G (continued)

```
4335 LOCATE 16,8:PRINT XZ$(10);:LOCATE 16,14:PRINT XZ$(2);
4340 LOCATE 16,48:PRINT XZ$(19);:LOCATE 16,62:PRINT XZ$(20);
4345 LOCATE 20,14:PRINT XZ$(1);:LOCATE 19,38:PRINT XZ$(11);
4350 LOCATE 19,67:PRINT XZ$(22);':LOCATE **,**:PRINT XZ$(**);
4355 IF Z$<>"R" THEN 4295 ELSE RETURN
4360 PAINT(328,128):PAINT(328,100):PAINT(383,83):PAINT(464,84):PAINT(464,124):PA
INT(528,124):RETURN
4365 '====================SCREEN STRING TRANSLATION======='
4370 XZ$="HIT <T> TEMP, <P> PRESSURE, <M> MOLE/HR, <H> ENTHALPY, <R> RETURN"
4375 LOCATE 25,1:PRINT XZ$;
4380 Z$=INKEY$:IF Z$<>"" THEN 4385 ELSE 4380
4385 IF Z$="T" THEN 4395 ELSE IF Z$="P" THEN 4400 ELSE IF Z$="M" THEN 4405 ELSE
IF Z$="H" THEN 4410 ELSE IF Z$="N" THEN 4415 ELSE 4420
4390 LOCATE 1,1:PRINT"SHIFT CONVERTER";
4395 FOR J=1 TO 30:XZ$(J)=" "+LEFT$(STR$(T(J)),5):XZ$(J)=RIGHT$(XZ$(J),4):NEXT J
:GOTO 4420
4400 FOR J=1 TO 30:XZ$(J)="   "+LEFT$(STR$(P(J)),4):XZ$(J)=RIGHT$(XZ$(J),4):NEXT
 J:GOTO 4420
4405 FOR J=1 TO 30:XZ$(J)=LEFT$(STR$(A(0,J)),4):NEXT J:GOTO 4420
4410 FOR J=1 TO 30:XZ$(J)=LEFT$(STR$(H(J)/1000),4):NEXT J:GOTO 4420
4415 FOR J=1 TO 30:XZ$(J)="<"+RIGHT$(STR$(J),2)+">":NEXT J:GOTO 4420
4420 RETURN
4425 '=============BURNER ANALYSIS================================
4430 A(1,23)=(3-2*PSI)*A(8,L3)/(FR(4,6)/FR(1,6)+1)
4435 A(1,7)=(1-UH)*A(1,23):A(2,7)=(2+PHI)*A(8,L3)-A(1,23):A(4,7)=(3-2*PSI)*A(8,L
3)-A(1,23):A(5,6)=((2*PSI-1)*A(8,L3)-A(4,6)+A(1,23))/2:A(7,7)=A(7,17)
4440 N=7:T(N)=TC:GOSUB 400:GOSUB 3410:GOSUB 10
4445 I9=7:J9=21:K9=8:GOSUB 910 ' MIX2
4450 IP=8:OP=9:GOSUB 1100:IC=5:NXN=576:MYM=44:GOSUB 4285:RETURN
4455 '=============ATR ANALYSIS===================================
4460 IP=16:OP=17:GOSUB 600:IF K(7)<>0 THEN N=17:T(N)=TT:GOSUB 10
4465 I9=17:J9=1:K9=2:GOSUB 910 'MIX 1
4470 IP=2:OP=3:GOSUB 600:N=3:T(N)=TATR:GOSUB 10
4472 LOCATE 1,1:PRINT"ATR ANALYSIS X=T(3), Y=T(4), YO=";TATR;:GOSUB 5000
4475 IP=3:OP=4:GOSUB 610:IF T(4)=TATR THEN J5=11:GOSUB 510:GOTO 4485
4480 J5=11:A5=J5:IC=1:X=T(3):Y=T(4):YO=TATR:EE=.1:GOSUB 440:T(3)=X:N=3:GOSUB 10:
IF K(J5)<>0 THEN 4472
4485 IC=5:NXN=96:MYM=60:GOSUB 4285:TREF3=T(3):RETURN
4490 '==============HX-2 ANALYSIS================================
4495 LOCATE 1,1:PRINT "HX2 RE-EVALUATION "
4500 IF N!(1)=0 OR N!(2)=0 THEN INPUT"INPUT N!(1) & N!(2)";N!(1),N!(2):N!=N!(2)
ELSE N!=N!(2)
```

MAIN PROGRAM CONFIGURATION GO41G (continued)

```
4502 LOCATE 1,1:PRINT"HX2 RE-EVALUATION","X=N!(2)","Y=T(5)","YO=TC+";DELT;:GOSUB
 5000
4505 IC=1:I7=4:J7=5:I8=16:J8=17:J3=6:GOSUB 1300:IF K(6)<>0 THEN 4505
4510 A5=10:IC=1:J5=10:X=N!:Y=T(J7):YO=TC+DELT:EE=.1:GOSUB 440:IF K(J5)=0 THEN 45
20
4512 IF X<0 THEN X=.1:N!=X:GOTO 4502
4513 IF X>10 THEN DELT=(1-.7*C8/C7)*(TATR-TC):GOTO 4502
4515 IF X<10 OR K(10)<10 THEN N!=X:GOTO 4502 ELSE GOSUB 510
4520 N!(2)=N!:IF C7>C8 THEN CS(2)=C8 ELSE CS(2)=C7
4525 IP=5:OP=24:GOSUB 600:IP=5:OP=0:T(OP)=400:GOSUB 900:IP=0:OP=5:GOSUB 600
4530 I9=17:J9=1:K9=2:GOSUB 910:IP=2:OP=3:GOSUB 600:N=3:T(N)=T(4):GOSUB 10'MIX 1
4536 IC=5:NXN=208:MYM=52:GOSUB 4290:RETURN
4540 '=============HX1==========================================
4545 CLS:IP=9:OP=10:GOSUB 600:N=OP:T(N)=T(2):GOSUB 10:IF K(7)=0 THEN N!(1)=3:N!=
N!(1) ELSE N!=N!(1)
4550 LOCATE 1,1:PRINT"HX1 ANALYSIS","X=N!","Y=T(3)","YO=T(4)";:GOSUB 5000
4555 I8=2:J8=3:I7=9:J7=10:J5=8:GOSUB 1300:IF K(J5)<>0 THEN 4555
4560 IC=1:A5=9:J5=9:X=N!:Y=T(3):YO=TREF3:EE=.06:GOSUB 440:N!=X:IF K(J5)=0 THEN 4
575
4565 IF N!<10 AND N!>0 THEN 4550 ELSE IF N!=<0 THEN N!=.1:GOTO 4550 ELSE IF N!>1
0 THEN GOSUB 510
4570 CLS:LOCATE 10,10:PRINT "HX 1 ANALYSIS FAILURE N!(1)=";N!:STOP
4575 IF C7>C8 THEN CS(1)=C8 ELSE CS(1)=C7
4577 N!(1)=N!:IC=5:NXN=48:MYM=104:GOSUB 4285:RETURN
4580 '==============SHIFT CONVERTER==============================
4585 IP=5:OP=6:GOSUB 1150:IC=5:NXN=272:MYM=44:GOSUB 4285:RETURN
4590 '====================FUEL CELL ANALYSIS==============
4595 IP=6:OP=23:GOSUB 600
4600 IP=6:OP=7:GOSUB 990'ANODE
4605 GOSUB 1200'PERF
4610 IC=4:AF$="FUEL CELL":AE$="6 7 1516":GOSUB 1980:LOCATE 23,10:PRINT"CURRENT D
ENSITY=";AF:LOCATE 24,10:PRINT"CELL VOLTS=";VO;
4615 LOCATE 25,1:PRINT "HIT ANY KEY TO CONTINUE";
4620 IF INKEY$="" THEN 4620 ELSE RETURN
4630 '===============DATA BASE FOR PARAMETRIC ANALYSIS================
4635 ICASE=ICASE+1
4640 OPEN "R",1,"SYS1.DAT"
4650 OPEN "R",2,"SYS2.DAT"
4660 OPEN "R",3,"SYS3.DAT"
```

MAIN PROGRAM CONFIGURATION GO41G (continued)

```
4670 FIELD 1, 2 AS ICA$,4 AS V1$,4 AS V2$,4 AS V3$,4 AS V4$,4 AS V5$,4 AS V6$,4
AS V7$,4 AS V8$,4 AS V9$,4 AS V10$
4680 FIELD 2,4 AS V11$,4 AS V12$,4 AS V13$,4 AS V14$,4 AS V15$,4 AS V16$,4 AS V1
7$,4 AS V18$,4 AS V19$,4 AS V20$
4690 FIELD 3,4 AS V21$,4 AS V22$,4 AS V23$,4 AS V24$,4 AS V25$,4 AS V26$,4 AS V2
7$,4 AS V28$,4 AS V29$
4695 LSET ICA$=MKI$(ICASE)
4700 LSET V1$=MKS$(PSI):LSET V2$=MKS$(UH):LSET V3$=MKS$(VO):LSET V4$=MKS$(T(L2))
:LSET V5$=MKS$(TATR):LSET V6$=MKS$(PG):LSET V7$=MKS$(PP):LSET V8$=MKS$(AF):LSET
V9$=MKS$(ATOT):LSET V10$=MKS$(NC)
4710 PUT 1,ICASE
4720 LSET V11$=MKS$(VSTACK):LSET V12$=MKS$(AMP):LSET V13$=MKS$(TC):LSET V14$=MKS
$(UO):LSET V15$=MKS$(BE)
4730 LSET V16$=MKS$(PHI):LSET V17$=MKS$(EO):LSET V18$=MKS$(ES):LSET V19$=MKS$(EM
):LSET V20$=MKS$(EI)
4740 PUT 2,ICASE
4750 LSET V21$=MKS$(EF):LSET V22$=MKS$(N!(1)):LSET V23$=MKS$(N!(2)):LSET V24$=MK
S$(Q(5)):LSET V25$=MKS$(CS(1))
4760 LSET V26$=MKS$(CS(2)):LSET V27$=MKS$(AREA(1)):LSET V28$=MKS$(AREA(2))
4770 PUT 3,ICASE
4780 CLOSE:RETURN
```

SYSM MODULE CONFIGURATION GO41G - PARAMETRICS

```
3000 REM SYSMG2 MODULE FOR G041G2 PARAMETRIC STUDIES 1/28/83
3005 DATA 5,.800,.58,.6,.6,.8,.25,1.2,1.3,1,4,70,70,375,375,375,35,1,345,1,.41,0
,500,.15,62.4,000,.34,30,2,2,5,.2,1400
3010 READ PN,PP,VO,UH,UO,EI,EO,BE,PHI,XN,XM,T(L2),T(L3),TC,T(L6),T(L7),DE,P,TB,N
B!,NT!,NJ!,T(IA),EF(7),RO,M,PD,DT,NC!,ND!,A(6,N6),PSI,TATR
3015 DATA .2,.15,.1,.6,.65,.7,.58,.60,.625,.650,70,90,105,125,1400,1200,1000,800

3021 FOR J=1 TO 3:READ XVAR1(J):PRINT J,XVAR1(J):NEXT
3022 FOR J=1 TO 3:READ XVAR2(J):PRINT J,XVAR2(J):NEXT
3023 FOR J=1 TO 4:READ XVAR3(J):PRINT J,XVAR3(J):NEXT
3024 FOR J=1 TO 4:READ XVAR4(J):PRINT J,XVAR4(J):NEXT
3025 FOR J=1 TO 4:READ XVAR5(J):PRINT J,XVAR5(J):NEXT:CLS
3026 GOSUB 1242
3030 FOR ICASE1=1 TO 3
3031 FOR ICASE2=1 TO 3
3032 FOR ICASE3=1 TO 4
3033 FOR ICASE4=1 TO 4
3034 FOR ICASE5=1 TO 4 :IF ITEST<ICASE THEN 3270
3040 PSI=XVAR1(ICASE1)
3045 UH=XVAR2(ICASE2)
3050 VO=XVAR3(ICASE3)
3055 T(L2)=XVAR4(ICASE4)
3060 TATR=XVAR5(ICASE5)
3065 FOR N=1 TO 25:P(N)=1:NEXT N
3075 EM=PN/(PN+PP):PG=PN/(EM*EI):HR=3957.2/EO
3080 ES=VO/1.2527:EF=1.0726*UH:EO=EF*EM*EI*ES
3085 A(8,L3)=.01174*PN/EO:A(1,L8)=.04112*PG/(VO*UH):REFH2=A(1,L8)
3090 N=L3:GOSUB 400:GOSUB 3410:LQ=1:GOSUB 10 '     DEF L3
3095 UO=A(1,L8)*UH/(A(1,L8)*UH+2*PSI*A(8,L3))
3100 A(6,L4)=A(1,L8)*UH/(2*UO):A(7,L4)=3.7733*A(6,L4):N=L4:GOSUB 400:GOSUB 3410:
GOSUB 10  '    DEF L4
3105 A(6,L7)=BE*(1.5*A(8,L3)-A(1,L8)*UH/2-PSI*A(8,L3)):A(7,L7)=3.7733*A(6,L7):N=
L7:GOSUB 400:GOSUB 3410:GOSUB 10'     DEF L7
3110 PHI=A(1,L8)*UH/A(8,L3)
3115 N=L6:A(6,N)=.2095:A(7,N)=1-A(6,N):GOSUB 400:GOSUB 3410:NH=3:GOSUB 10 '   DEF
 L6
3120 QS=3413*PG*(1-ES)/ES
```

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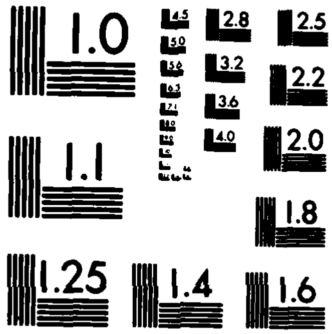
END



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SYSM MODULE GO41G - PARAMETRICS (continued)

```
3125 A(0,N)=DS/(CP*(T(N)-250)):GOSUB 3420:GOSUB 10
3130 FOR J=15 TO 22:T(J)=T(N):NEXT
3135 IP=L6:FOR OP=12 TO 13:N=OP:GOSUB 600:T(N)=250:GOSUB 10:NEXT 'DEF 12,13
3140 I9=L6:J9=L4:K9=18:F=A(0,J9)/A(0,I9):GOSUB 880 ' DEF 18
3145 A(0,L2)=A(0,12)*(T(19)-T(12))/(T(19)-T(L2)):N=L2:FR(6,N)=.2095:FR(7,N)=1-.2
095:GOSUB 3420:GOSUB 10 '    DEF L2
3150 A(0,19)=A(0,12)-A(0,L2):F=A(0,19)/A(0,18):I9=18:J9=19:K9=20:GOSUB 880 '   DE
F 19,20
3155 I9=20:J9=21:K9=22:F=A(6,21)/A(6,20):GOSUB 880 'DEF 21,22
3160 IP=15:OP=16:GOSUB 600:GOSUB 950 'DEF 16
3162 IF IRECAL=1 THEN 4180
3165 IRECAL =0:GOSUB 3200:GOSUB 4030
3172 NEXT ICASE5
3177 NEXT ICASE4
3182 NEXT ICASE3
3187 NEXT ICASE2
3192 NEXT ICASE1:GOTO 3260
3200 CLS:LOCATE 10,10:PRINT "ICASE1=";ICASE1,"PSI=";PSI
3210 LOCATE 11,10:PRINT"ICASE2=";ICASE2,"UH=";UH
3220 LOCATE 12,10:PRINT"ICASE3=";ICASE3,"VO=";VO
3230 LOCATE 13,10:PRINT"ICASE4=";ICASE4,"T(L2)=";T(L2)
3240 LOCATE 14,10:PRINT"ICASE5=";ICASE5,"TATR=";TATR
3245 LOCATE 16,10:PRINT"ICASE=";ICASE+1
3247 LOCATE 17,10:PRINT"IFAIL=";IFAIL
3250 RETURN
3260 END
3270 ITEST=ITEST+1:IF ITEST=ICASE-1 THEN ITEST=577:ICASE=ICASE-IFAIL-1
3280 LOCATE 10,10:PRINT "ITEST=";ITEST:GOTO 3172
```

MAIN PROGRAM CONFIGURATION GO41G - PARAMETRICS

```
4000 '===============G041G2 MAIN=====1/29/84=================='
4001 '===============SYSM SETUP================================'
4002 INPUT"INPUT START CASE 1 (1-3)";IST1:IF IST1=0 THEN 4002
4003 INPUT"INPUT START CASE 2 (1-3)";IST2:IF IST2=0 THEN 4003
4004 INPUT"INPUT START CASE 3 (1-4)";IST3:IF IST3=0 THEN 4004
4005 INPUT"INPUT START CASE 4 (1-4)";IST4:IF IST4=0 THEN 4005
4006 INPUT"INPUT START CASE 5 (1-4)";IST5:IF IST1=0 THEN 4006
4007 INPUT"INPUT NUMBER OF FAILURES - IFAIL";IFAIL
4009 ICASE=576*(IST1-1)/3+576*(IST2-1)/(3*3)+576*(IST3-1)/(3*3*4)+576*(IST4-1)/(
3*3*4*4)+576*(IST5-1)/(3*3*4*4*4)+1
4018 L2=11:L3=1:L4=15:L6=14:L7=21:L8=6:KEY OFF:CLS
4019 '====================ACCESS SYSM===================
4020 GOTO 3000
```

MAIN PROGRAM CONFIGURATION GO41G - PARAMETRICS (continued)

```
4030 IP=16:OP=17:GOSUB 600
4035 '===============ATR ANALYSIS==================================
4040 LOCATE 1,1:PRINT"ATR ANALYSIS";
4045 EF(1)=.7:T(4)=TATR:N=17:T(N)=T(16)+EF(1)*(T(4)-T(16)):GOSUB 10
4050 T(4)=TATR:T(3)=T(4):GOSUB 4465:N!(2)=5
4055 '==============HX 2 APPROXIMATION==========================
4057 IP=4:OP=5:GOSUB 600:N=5:T(N)=800:GOSUB 10
4060 LOCATE 1,1:PRINT "HX2 ANALYSIS";:GOSUB 5000
4065 N!=N!(2):I7=4:J7=5:I8=16:J8=17:J5=6:IC=1:A5=J5:GOSUB 1300:IF K(6)<>0 THEN 4
060
4070 IF T(5)<400 AND T(5)>350 THEN 4085
4075 IP=5:OP=24:GOSUB 600:IP=5:OP=0:T(OP)=400:GOSUB 900:IP=0:OP=5:GOSUB 600
4080 IC=5:NXN=208:MYM=52:GOSUB 4285
4082 DELT=T(24)-TC
4085 GOSUB 4580
4090 '=====================FUEL CELL ANALYSIS=============
4095 GOSUB 4590
4100 '==============MIX2========================================
4105 LOCATE 1,1:PRINT"MIX2 ANALYSIS";
4110 I9=7:J9=21:K9=8:GOSUB 910
4115 '==============BURN========================================
4120 LOCATE 1,1:PRINT"BURNER ANALYSIS";
4125 GOSUB 4450
4130 '==============HX1=========================================
4135 GOSUB 4540
4140 '==============FUEL CLOSURE=================================
4145 LOCATE 1,1:PRINT"FUEL CLOSURE ANALYSIS":PRINT"ITERATION K(7)=";K(7)
4150 J5=7:X=A(8,L3):Y=A(1,6):Y0=REFH2:EE=.03:GOSUB 440:A(8,L3)=X:IF K(J5)=0 THEN
 4255 ELSE GOSUB 5000
4155 EO=.01174*FN/A(8,L3):EF=EO/(ES*EI*EM)
4170 '==============SYSM RECALL=================================
4175 TT=T(17):LOCATE 1,1:PRINT "SYSM RECALL";:IRECAL=1:GOTO 3090:N!=N!(2)
4180 IP=16:OP=17:GOSUB 600:N=17:T(N)=TT:GOSUB 10
4185 GOSUB 4425' BURNER
4190 GOSUB 4455' ATR
4195 IP=4:OP=5:GOSUB 600:T(5)=T(24):GOSUB 10:GOSUB 4490' HX2
4200 GOSUB 4540' HX1
4205 GOSUB 4500' SHIFT
4210 GOSUB 4590' FUEL CELL
4215 GOTO 4140
4220 '==============END FUEL CLOSURE LOOP=======================
4225 '            START MAIN PROGRAM SUBROUTINES
4245 I1=8:I2=9:I3=4:IA=27:I4=27  'NODE 27 IS A DUMMY OF NODE 11
```

MAIN PROGRAM GO41G PARAMETRICS (continued)

```
4250 GOSUB 4290:A5=2:IC=1:NT!=1
4255 '====================ANALYSIS COMPLETE==============
4275 GOSUB 4630:GOSUB 4880
4283 RETURN
4285 '=====================CONFIGURATION SCREEN============
4290 RETURN
4425 '=============BURNER ANALYSIS==============================
4430 A(1,23)=(3-2*PSI)*A(8,L3)/(FR(4,6)/FR(1,6)+1)
4435 A(1,7)=(1-UH)*A(1,23):A(2,7)=(2+PHI)*A(8,L3)-A(1,23):A(4,7)=(3-2*PSI)*A(8,L
3)-A(1,23):A(5,6)=((2*PSI-1)*A(8,L3)-A(4,6)+A(1,23))/2:A(7,7)=A(7,17)
4440 N=7:T(N)=TC:GOSUB 400:GOSUB 3410:GOSUB 10
4445 I9=7:J9=21:K9=8:GOSUB 910 ' MIX2
4450 IP=8:OP=9:GOSUB 1100:IC=5:NXN=576:MYM=44:GOSUB 4285:RETURN
4455 '=============ATR ANALYSIS====================================
4460 IP=16:OP=17:GOSUB 600:IF K(7)<>0 THEN N=17:T(N)=TT:GOSUB 10
4465 I9=17:J9=1:K9=2:GOSUB 910 'MIX 1
4470 IP=2:OP=3:GOSUB 600:N=3:T(N)=TATR:GOSUB 10
4472 LOCATE 1,1:PRINT"ATR ANALYSIS X=T(3), Y=T(4), YO=";TATR;:GOSUB 5000
4475 IP=3:OP=4:GOSUB 610:IF T(4)=TATR THEN J5=11:GOSUB 510:GOTO 4485
4480 J5=11:A5=J5:IC=1:X=T(3):Y=T(4):YO=TATR:EE=.1:GOSUB 440:T(3)=X:N=3:GOSUB 10:
IF K(J5)<>0 THEN 4472
4485 IC=5:NXN=96:MYM=60:GOSUB 4285:TREF3=T(3):RETURN
4490 '==============HX-2 ANALYSIS================================
4495 LOCATE 1,1:PRINT "HX2 RE-EVALUATION "
4500 IF N!(1)=0 OR N!(2)=0 THEN INPUT"INPUT N!(1) & N!(2)";N!(1),N!(2):N!=N!(2)
ELSE N!=N!(2)
4502 LOCATE 1,1:PRINT"HX2 RE-EVALUATION","X=N!(2)","Y=T(5)","YO=TC+";DELT;:GOSUB
 5000
4505 IC=1:I7=4:J7=5:I8=16:J8=17:J5=6:GOSUB 1300:IF K(6)<>0 THEN 4505
4510 A5=10:IC=1:J5=10:X=N!:Y=T(J7):YO=TC+DELT:EE=.1:GOSUB 440:IF K(J5)=0 THEN 45
20
4512 IF X=<0 THEN X=.1:N!=X:GOTO 4502
4513 IF X>10 THEN DELT=(1-.7*CB/C7)*(TATR-TC):GOTO 4502
4515 IF X<10 OR K(10)<10 THEN N!=X:GOTO 4502 ELSE GOSUB 510
4520 N!(2)=N!:IF C7>CB THEN CS(2)=CB ELSE CS(2)=C7
4525 IP=5:OP=24:GOSUB 600:IP=5:OP=0:T(OP)=400:GOSUB 900:IP=0:OP=5:GOSUB 600
4530 I9=17:J9=1:K9=2:GOSUB 910:IP=2:OP=3:GOSUB 600:N=3:T(N)=T(4):GOSUB 10'MIX 1
4536 IC=5:NXN=208:MYM=52:GOSUB 4290:RETURN
4540 '=============HX1=======================================
```

```
4545 IP=9:OP=10:GOSUB 600:N=OP:T(N)=T(2):GOSUB 10:IF K(7)=0 THEN N!(1)=3:N!=N!(1
) ELSE N!=N!(1)
4550 LOCATE 1,1:PRINT"HX1 ANALYSIS","X=N!","Y=T(3)","YO=T(4)";:GOSUB 5000
4555 I8=2:J8=3:I7=9:J7=10:J5=8:GOSUB 1300:IF K(J5)<>0 THEN 4555
4560 IC=1:A5=9:J5=9:X=N!:Y=T(3):YO=TREF3:EE=.06:GOSUB 440:N!=X:IF K(J5)=0 THEN 4
575
4565 IF N!<10 AND N!>0 THEN 4550 ELSE IF N!=<0 THEN N!=.1:GOTO 4550 ELSE IF N!>1
0 THEN GOSUB 510
4570 LOCATE 10,10:PRINT "HX 1 ANALYSIS FAILURE N!(1)=";N!:ERROR 79
4575 IF C7>C8 THEN CS(1)=C8 ELSE CS(1)=C7
4577 N!(1)=N!:IC=5:NXN=48:MYM=104:GOSUB 4285:RETURN
4580 '==============SHIFT CONVERTER=============================
4585 IP=5:OP=6:GOSUB 1150:IC=5:NXN=272:MYM=44:GOSUB 4285:RETURN
4590 '=====================FUEL CELL ANALYSIS==============
4595 IP=6:OP=23:GOSUB 600
4600 IP=6:OP=7:GOSUB 990'ANODE
4605 GOSUB 1200'PERF
4620 RETURN
4630 '===============DATA BASE FOR PARAMETRIC ANALYSIS=================
4631 ATOT=PG*1000/(VO*AF):NC=ATOT/1.4:VSTACK=NC*VO:AMP=1.4*AF
4632 AREA(1)=N!(1)*CS(1)/10:AREA(2)=N!(2)*CS(2)/10
4633 ACFM4=A(0,4)*.011934*(T(4)+460):ACFM9=A(0,9)*.011934*(T(9)+460):ACFM12=A(0,
12)*.011934*(T(12)+460):ACFM11=A(0,11)*.011934*(T(11)+460)
4635 ICASE=ICASE+1
4637 LOCATE 25,1:PRINT"SAVING CASE DATA";:BEEP
4640 OPEN "R",1,"SYS1G2.DAT"
4650 OPEN "R",2,"SYS2G2.DAT"
4660 OPEN "R",3,"SYS3G2.DAT"
4670 FIELD 1, 2 AS ICA$,4 AS V1$,4 AS V2$,4 AS V3$,4 AS V4$,4 AS V5$,4 AS V6$,4
AS V7$,4 AS V8$,4 AS V9$,4 AS V10$
4680 FIELD 2,4 AS V11$,4 AS V12$,4 AS V13$,4 AS V14$,4 AS V15$,4 AS V16$,4 AS V1
7$,4 AS V18$,4 AS V19$,4 AS V20$
4690 FIELD 3,4 AS V21$,4 AS V22$,4 AS V23$,4 AS V24$,4 AS V25$,4 AS V26$,4 AS V2
7$,4 AS V28$,4 AS V29$
4695 LSET ICA$=MKI$(ICASE)
```

MAIN PROGRAM CONFIGURATION G041G - PARAMETRICS (continued)

```
4700 LSET V1$=MKS$(FSI):LSET V2$=MKS$(UH):LSET V3$=MKS$(VO):LSET V4$=MKS$(T(L2))
:LSET V5$=MKS$(TATR):LSET V6$=MKS$(ACFM9):LSET V7$=MKS$(ACFM11):LSET V8$=MKS$(AF
):LSET V9$=MKS$(ATOT):LSET V10$=MKS$(NC)
4710 PUT 1,ICASE
4720 LSET V11$=MKS$(VSTACK):LSET V12$=MKS$(AMP):LSET V13$=MKS$(TC):LSET V14$=MKS
$(UO):LSET V15$=MKS$(ACFM12)
4730 LSET V16$=MKS$(PHI):LSET V17$=MKS$(EO):LSET V18$=MKS$(ES):LSET V19$=MKS$(EM
):LSET V20$=MKS$(EI)
4740 PUT 2,ICASE
4750 LSET V21$=MKS$(EF):LSET V22$=MKS$(N!(1)):LSET V23$=MKS$(N!(2)):LSET V24$=MK
S$(Q(5)):LSET V25$=MKS$(CS(1))
4760 LSET V26$=MKS$(CS(2)):LSET V27$=MKS$(AREA(1)):LSET V28$=MKS$(AREA(2)):LSET
V29$=MKS$(ACFM4)
4770 PUT 3,ICASE
4777 LOCATE 25,1:PRINT"                              ";
4780 CLOSE:RETURN
4800 '===============ERROR TRAPPING FOR G041G2 PARAMETRICS============
4850 GOSUB 4860:LPRINT"CASE ERROR":RESUME 3172
4860 LPRINT"ANALYSIS FAILURE AT CONFIGURATION":LPRINT ICASE1,ICASE2,ICASE3,ICASE
4,ICASE5
4870 LPRINT "FSI=";FSI,"UH=";UH,"VO=";VO,"T(L2)=";T(L2),"TATR=";TATR
4880 T1S=T(L2):T2S=T(L3):T3S=T(L3):T4S=T(L6):T5S=T(L7):T6S=T(3):T7S=T(24)
4890 FOR N=1 TO 24:GOSUB 410:NEXT
4895 T(L2)=T1S:T(L3)=T2S:T(L3)=T3S:T(L6)=T4S:T(L7)=T5S:T(3)=T6S:T(24)=T7S
4900 FOR J5=1 TO 15:GOSUB 510:NEXT
4910 IFAIL=IFAIL+1:IRECAL=0:RETURN
```

READSYS PROGRAM CONFIGURATION GO41G

```
10 'READSYS.BAS  1/28/83
12 KEY OFF:CLS:LOCATE 10,15:PRINT"READSYS.BAS DATA BASE DISPLAY"
20 ICASE=ICASE+1
30 OPEN "R",1,"SYS1G2.DAT"
40 OPEN "R",2,"SYS2G2.DAT"
50 OPEN "R",3,"SYS3G2.DAT"
60 FIELD 1, 2 AS ICA$,4 AS V1$,4 AS V2$,4 AS V3$,4 AS V4$,4 AS V5$,4 AS V6$,4 AS
 V7$,4 AS V8$,4 AS V9$,4 AS V10$
70 FIELD 2,4 AS V11$,4 AS V12$,4 AS V13$,4 AS V14$,4 AS V15$,4 AS V16$,4 AS V17$
,4 AS V18$,4 AS V19$,4 AS V20$
80 FIELD 3,4 AS V21$,4 AS V22$,4 AS V23$,4 AS V24$,4 AS V25$,4 AS V26$,4 AS V27$
,4 AS V28$,4 AS V29$
90 INPUT"INPUT CASE";ICASE:GET 1,ICASE:GET 2,ICASE:GET 3,ICASE
100 ICA=CVI(ICA$):CLS:LOCATE 10,10:PRINT "ICASE =";ICA
110 PSI=CVS(V1$):UH=CVS(V2$):VO=CVS(V3$):T(L2)=CVS(V4$):TATR=CVS(V5$):ACFM9=CVS(
V6$):ACFM11=CVS(V7$):AF=CVS(V8$):ATOT=CVS(V9$):NC=CVS(V10$)
120 VSTACK=CVS(V11$):AMP=CVS(V12$):TC=CVS(V13$):UO=CVS(V14$):ACFM12=CVS(V15$)
130 PHI=CVS(V16$):EO=CVS(V17$):ES=CVS(V18$):EM=CVS(V19$):EI=CVS(V20$)
140 EF=CVS(V21$):N!(1)=CVS(V22$):N!(2)=CVS(V23$):Q(5)=CVS(V24$):CS(1)=CVS(V25$)
150 CS(2)=CVS(V26$):AREA(1)=CVS(V27$):AREA(2)=CVS(V28$):ACFM4=CVS(V29$)
160 CLOSE
170 REM OUTPUT PRINT SYSTEM DATA BLOCK
180 PRINT "SYSTEM DATA BLOCK"
190 PRINT "PARAMETRIC STUDY PARAMETERS":PRINT"":PRINT "ATR O2/C= ";PSI
200 PRINT "HYDROGEN UTILIZATION ";UH
210 PRINT "CELL VOLTS =";VO
220 PRINT "AIR INLET TEMP=";T(L2)
230 PRINT "ATR EXIT TEMP, DEFAULT =";TATR
240 PRINT "POWER (KW)"
```

READSYS CONFIGURATION GO41G (continued)

```
250 PRINT TAB(10)  "NET=";5,"GROSS=";7.25,"PARASITE=";.8
260 PRINT TAB(10)   "CELL VOLTAGE=";VO,"CURRENT DENSITY=";AF;"  ASF"
270 PRINT TAB(10)"FUEL CELL AREA=";ATOT;" SQFT"
280 PRINT TAB(10)"NUMBER OF CELLS @ 1.4 FT2=";NC
290 PRINT TAB(10)"STACK VOLTS=";VSTACK
300 PRINT TAB(10)"STACK CURRENT=";AMP";AMP":PRINT
310 PRINT TAB(10)"CELL TEMPERATURE=";TC;"DEG F"
320 PRINT "UTILIZATIONS"
330 PRINT TAB(10)  "HYDROGEN=";UH,"AIR(STACK)=";UO
340 PRINT TAB(10)"BURNER ENRICHMENT=";1.2:PRINT
345 IF INKEY$="" THEN 345 ELSE CLS
350 PRINT"ATR FUEL PROCESSOR OUTPUT"
360 PRINT"WATER TO FUEL RATIO=";PHI,"O2/FUEL RATIO=";PSI
370 PRINT "EFFICIENCY"
380 PRINT TAB(10)"OVERALL=";EO
390 PRINT TAB(10)  "FUEL CELL=";ES,"MECHANICAL=";EM
400 PRINT TAB(10)"INVERTER=";EI,"FUEL PROCESSOR=";EF:PRINT
410 PRINT "HX DATA NTU"
420 PRINT TAB(10)  "HX-1=";N!(1),"HX-2=";N!(2)
430 'ASSUMED U=10
440 PRINT "HEAT EXCHANGER AREA"
450 PRINT TAB(20)"HX 1 AREA=";AREA(1);" FT2","HX 2 AREA=";AREA(2);" FT2"
460 PRINT "QBAL DATA"
470 PRINT TAB(20)"Q(5)=";Q(5)
480 PRINT"FLOW DATA - ACFM"
490 PRINT TAB(20)"ACFM4=";ACFM4,"ACFM9=";ACFM9
500 PRINT TAB(20)"ACFM11=";ACFM11,"ACFM12=";ACFM12
510 END
```

WRITESYS CONFIGURATION GO41G

```
10 'WRITESYS.BAS  1/28/83
20 KEY OFF:CLS:LOCATE 10,15:PRINT"WRITESYS.BAS DATA BASE"
30 DIM XVAR(450,30)
40 OPEN "R",1,"C:SYS1G2.DAT"
50 OPEN "R",2,"C:SYS2G2.DAT"
60 OPEN "R",3,"C:SYS3G2.DAT"
70 FIELD 1, 2 AS ICA$,4 AS V1$,4 AS V2$,4 AS V3$,4 AS V4$,4 AS V5$,4 AS V6$,4 AS
 V7$,4 AS V8$,4 AS V9$,4 AS V10$
80 FIELD 2,4 AS V11$,4 AS V12$,4 AS V13$,4 AS V14$,4 AS V15$,4 AS V16$,4 AS V17$
,4 AS V18$,4 AS V19$,4 AS V20$
90 FIELD 3,4 AS V21$,4 AS V22$,4 AS V23$,4 AS V24$,4 AS V25$,4 AS V26$,4 AS V27$
,4 AS V28$,4 AS V29$
100 INPUT"INPUT NUMBER OF CASES";ICASE
110 FOR I=1 TO ICASE:GET 1,I:GET 2,I:GET 3,I
120 ICA=CVI(ICA$):CLS:LOCATE 10,10:PRINT "ICASE =";ICA
130 PSI=CVS(V1$):UH=CVS(V2$):VO=CVS(V3$):T(L2)=CVS(V4$):TATR=CVS(V5$):ACFM9=CVS(
V6$):ACFM11=CVS(V7$):AF=CVS(V8$):ATDT=CVS(V9$):NC=CVS(V10$)
140 VSTACK=CVS(V11$):AMP=CVS(V12$):TC=CVS(V13$):UO=CVS(V14$):ACFM12=CVS(V15$)
150 PHI=CVS(V16$):EO=CVS(V17$):ES=CVS(V18$):EM=CVS(V19$):EI=CVS(V20$)
160 EF=CVS(V21$):N!(1)=CVS(V22$):N!(2)=CVS(V23$):Q(5)=CVS(V24$):CS(1)=CVS(V25$)
170 CS(2)=CVS(V26$):AREA(1)=CVS(V27$):AREA(2)=CVS(V28$):ACFM4=CVS(V29$)
180 XVAR(ICA,1)= PSI
190 XVAR(ICA,2)= UH
200 XVAR(ICA,3)= VO
210 XVAR(ICA,4)= T(L2)
220 XVAR(ICA,5)= TATR
230 XVAR(ICA,6)= PN:XVAR(ICA,7)=PG:XVAR(ICA,8)=PP
240 XVAR(ICA,9)= VO:XVAR(ICA,10)=AF
```

WRITESYS CONFIGURATION G041G (continued)

```
250 XVAR(ICA,11)= ATOT
260 XVAR(ICA,12)= NC
270 XVAR(ICA,13)= VSTACK
280 XVAR(ICA,14)= AMP
290 XVAR(ICA,15)= TC
300 XVAR(ICA,16)= UH:XVAR(ICA,17)=UO
310 XVAR(ICA,18)= BE
320 XVAR(ICA,19)= PHI:XVAR(ICA,20)=PSI
330 XVAR(ICA,21)= EO
340 XVAR(ICA,22)= ES:XVAR(ICA,23)=EF
350 XVAR(ICA,24)= AREA(1):XVAR(ICA,25)=AREA(2)
360 XVAR(ICA,26)= ACFM4:XVAR(ICA,27)=ACFM9
370 XVAR(ICA,28)= ACFM11:XVAR(ICA,29)=ACFM12
380 XVAR(ICA,30)= Q(5)
390 NEXT I
400 CLOSE
410 OPEN"O",1,"G041G2.PRN"
420 FOR I=1 TO ICASE:LOCATE 1,1:PRINT"I=";I;"J=";SPC(76);
425 FOR J=1 TO 30:PRINT J;
430 IF J=6 OR J=7 OR J=8 OR J=9 OR J=15 OR J=16 OR J=18 OR J=20 THEN 490
450 X$=STR$(XVAR(I,J)):V=LEN(X$):X$=RIGHT$(X$,V-1)
460 FOR L=9 TO V STEP -1:XX$=XX$+" ":NEXT L
470 X$=X$+XX$:XX$=""
480 PRINT#1,X$;:GOTO 490
490 NEXT J
500 PRINT#1,CHR$(13);:GOTO 510
510 NEXT I
520 CLOSE
530 END
```

LISTING DATA FILE GO41G-2.WKS

604162.WKS
THIS FILE IS FOR USE IN CONJUCTION WITH 604162.PRN FILES
COMMON PARAMETERS

PNET	5.000 KW	EFFICIENCY	
PGROSS	7.250 KW	MECH	0.862
PARASITE	0.800 KW	INV	0.800

TCELL 375.000 DEGF
BURN ENR 1.200

CASE	INDEPENDENT VARIABLES O2/C	UH	CELL VOLTS	AMBIENT TEMP	TATR	CURRENT DENSITY ASF	STACK AREA FT2	NUMBER CELLS	STACK VOLTS	STACK AMP	OXYGEN UTIL	H2O/C
1	0.200	0.600	0.580	70	1400	148.199	84.346	60	34.800	207.479	0.773	1.362
2	0.200	0.600	0.580	70	1200	150.110	83.272	59	34.220	210.155	0.773	1.360
3	0.200	0.600	0.580	70	1000	152.461	81.988	59	34.220	213.445	0.772	1.356
4	0.200	0.600	0.580	70	800	155.146	80.569	58	33.640	217.204	0.772	1.351
5	0.200	0.600	0.580	90	1400	148.199	84.346	60	34.800	207.479	0.773	1.362
6	0.200	0.600	0.580	90	1200	150.110	83.272	59	34.220	210.155	0.773	1.360
7	0.200	0.600	0.580	90	1000	152.461	81.988	59	34.220	213.445	0.772	1.356
8	0.200	0.600	0.580	90	800	155.146	80.569	58	33.640	217.204	0.772	1.351
9	0.200	0.600	0.580	105	1400	148.199	84.346	60	34.800	207.479	0.773	1.362
10	0.200	0.600	0.580	105	1200	150.110	83.272	59	34.220	210.155	0.773	1.360
11	0.200	0.600	0.580	105	1000	152.461	81.988	59	34.220	213.445	0.772	1.356
12	0.200	0.600	0.580	105	800	155.146	80.569	58	33.640	217.204	0.772	1.351
13	0.200	0.600	0.580	125	1400	148.199	84.346	60	34.800	207.479	0.773	1.362
14	0.200	0.600	0.580	125	1200	150.110	83.272	59	34.220	210.155	0.773	1.360
15	0.200	0.600	0.580	125	1000	152.461	81.988	59	34.220	213.445	0.772	1.356
16	0.200	0.600	0.580	125	800	155.146	80.569	58	33.640	217.204	0.772	1.351
17	0.200	0.600	0.600	70	1400	119.204	101.367	72	43.200	166.885	0.773	1.362
18	0.200	0.600	0.600	70	1200	120.844	99.992	71	42.600	169.181	0.773	1.360
19	0.200	0.600	0.600	70	1000	122.866	98.346	70	42.000	172.012	0.772	1.356
20	0.200	0.600	0.600	70	800	125.188	96.522	69	41.400	175.263	0.772	1.351
21	0.200	0.600	0.600	90	1400	119.204	101.367	72	43.200	166.885	0.773	1.362
22	0.200	0.600	0.600	90	1200	120.844	99.992	71	42.600	169.181	0.773	1.360
23	0.200	0.600	0.600	90	1000	122.866	98.346	70	42.000	172.012	0.772	1.356
24	0.200	0.600	0.600	90	800	125.188	96.522	69	41.400	175.263	0.772	1.351
25	0.200	0.600	0.600	105	1400	119.204	101.367	72	43.200	166.885	0.773	1.362
26	0.200	0.600	0.600	105	1200	120.844	99.992	71	42.600	169.181	0.773	1.360
27	0.200	0.600	0.600	105	1000	122.866	98.346	70	42.000	172.012	0.772	1.356
28	0.200	0.600	0.600	105	800	125.188	96.522	69	41.400	175.263	0.772	1.351
29	0.200	0.600	0.600	125	1400	119.204	101.367	72	43.200	166.885	0.773	1.362
30	0.200	0.600	0.600	125	1200	120.844	99.992	71	42.600	169.181	0.773	1.360
31	0.200	0.600	0.600	125	1000	122.866	98.346	70	42.000	172.012	0.772	1.356
32	0.200	0.600	0.600	125	800	125.188	96.522	69	41.400	175.263	0.772	1.351
33	0.200	0.600	0.625	70	1400	86.865	133.541	95	59.375	121.611	0.773	1.362
34	0.200	0.600	0.625	70	1200	88.200	131.520	94	58.750	123.480	0.773	1.360
35	0.200	0.600	0.625	70	1000	89.854	129.099	92	57.500	125.795	0.772	1.356
36	0.200	0.600	0.625	70	800	91.763	126.412	90	56.250	128.469	0.772	1.351
37	0.200	0.600	0.625	90	1400	86.865	133.541	95	59.375	121.611	0.773	1.362
38	0.200	0.600	0.625	90	1200	88.200	131.520	94	58.750	123.480	0.773	1.360
39	0.200	0.600	0.625	90	1000	89.854	129.099	92	57.500	125.795	0.772	1.356
40	0.200	0.600	0.625	90	800	91.763	126.412	90	56.250	128.469	0.772	1.351
41	0.200	0.600	0.625	105	1400	86.865	133.541	95	59.375	121.611	0.773	1.362
42	0.200	0.600	0.625	105	1200	88.200	131.520	94	58.750	123.480	0.773	1.360

43	0.200	0.600	0.625	105	1000	89.854	129.099	92	57.500	125.795	0.772	1.356
44	0.200	0.600	0.625	105	800	91.763	126.412	90	56.250	128.469	0.772	1.351
45	0.200	0.600	0.625	125	1400	86.865	133.541	95	59.375	121.611	0.773	1.362
46	0.200	0.600	0.625	125	1200	88.200	131.520	94	58.750	123.480	0.773	1.360
47	0.200	0.600	0.625	125	1000	89.854	129.099	92	57.500	125.795	0.772	1.356
48	0.200	0.600	0.625	125	800	91.763	126.412	90	56.250	128.469	0.772	1.351
49	0.200	0.600	0.650	70	1400	59.361	187.899	134	87.100	83.105	0.773	1.362
50	0.200	0.600	0.650	70	1200	60.412	184.629	132	85.800	84.577	0.773	1.360
51	0.200	0.600	0.650	70	1000	61.721	180.714	129	83.850	86.409	0.772	1.356
52	0.200	0.600	0.650	70	800	63.242	176.368	126	81.900	88.539	0.772	1.351
53	0.200	0.600	0.650	90	1400	59.361	187.899	134	87.100	83.105	0.773	1.362
54	0.200	0.600	0.650	90	1200	60.412	184.629	132	85.800	84.577	0.773	1.360
55	0.200	0.600	0.650	90	1000	61.721	180.714	129	83.850	86.409	0.772	1.356
56	0.200	0.600	0.650	90	800	63.242	176.368	126	81.900	88.539	0.772	1.351
57	0.200	0.600	0.650	105	1400	59.361	187.899	134	87.100	83.105	0.773	1.362
58	0.200	0.600	0.650	105	1200	60.412	184.629	132	85.800	84.577	0.773	1.360
59	0.200	0.600	0.650	105	1000	61.721	180.714	129	83.850	86.409	0.772	1.356
60	0.200	0.600	0.650	105	800	63.242	176.368	126	81.900	88.539	0.772	1.351
61	0.200	0.600	0.650	125	1400	59.361	187.899	134	87.100	83.105	0.773	1.362
62	0.200	0.600	0.650	125	1200	60.412	184.629	132	85.800	84.577	0.773	1.360
63	0.200	0.600	0.650	125	1000	61.721	180.714	129	83.850	86.409	0.772	1.356
64	0.200	0.600	0.650	125	800	63.242	176.368	126	81.900	88.539	0.772	1.351
65	0.200	0.650	0.580	70	1400	145.144	86.121	62	35.960	203.201	0.786	1.473
66	0.200	0.650	0.580	70	800	151.686	82.407	59	34.220	212.361	0.785	1.461
67	0.200	0.650	0.580	90	1400	145.144	86.121	62	35.960	203.201	0.786	1.473
68	0.200	0.650	0.580	90	800	151.686	82.407	59	34.220	212.361	0.785	1.461
69	0.200	0.650	0.580	105	1400	145.144	86.121	62	35.960	203.201	0.786	1.473
70	0.200	0.650	0.580	105	800	151.686	82.407	59	34.220	212.361	0.785	1.461
71	0.200	0.650	0.580	125	1400	145.144	86.121	62	35.960	203.201	0.786	1.473
72	0.200	0.650	0.580	125	800	151.686	82.407	59	34.220	212.361	0.785	1.461
73	0.200	0.650	0.600	70	1400	116.299	103.899	74	44.400	162.818	0.786	1.473
74	0.200	0.650	0.600	70	800	121.970	99.068	71	42.600	170.759	0.785	1.461
75	0.200	0.650	0.600	90	1400	116.299	103.899	74	44.400	162.818	0.786	1.473
76	0.200	0.650	0.600	90	800	121.970	99.068	71	42.600	170.759	0.785	1.461
77	0.200	0.650	0.600	105	1400	116.299	103.899	74	44.400	162.818	0.786	1.473
78	0.200	0.650	0.600	105	800	121.970	99.068	71	42.600	170.759	0.785	1.461
79	0.200	0.650	0.600	125	1400	116.299	103.899	74	44.400	162.818	0.786	1.473
80	0.200	0.650	0.600	125	800	121.970	99.068	71	42.600	170.759	0.785	1.461
81	0.200	0.650	0.625	70	1400	84.244	137.695	98	61.250	117.942	0.786	1.473
82	0.200	0.650	0.625	70	800	88.914	130.463	93	58.125	124.480	0.785	1.461
83	0.200	0.650	0.625	90	1400	84.244	137.695	98	61.250	117.942	0.786	1.473
84	0.200	0.650	0.625	90	800	88.914	130.463	93	58.125	124.480	0.785	1.461
85	0.200	0.650	0.625	105	1400	84.244	137.695	98	61.250	117.942	0.786	1.473
86	0.200	0.650	0.625	105	800	88.914	130.463	93	58.125	124.480	0.785	1.461
87	0.200	0.650	0.625	125	1400	84.244	137.695	98	61.250	117.942	0.786	1.473
88	0.200	0.650	0.625	125	800	88.914	130.463	93	58.125	124.480	0.785	1.461
89	0.200	0.650	0.650	70	1400	57.135	195.219	139	90.350	79.989	0.786	1.473
90	0.200	0.650	0.650	70	800	60.842	183.324	131	85.150	85.179	0.785	1.461
91	0.200	0.650	0.650	90	1400	57.135	195.219	139	90.350	79.989	0.786	1.473
92	0.200	0.650	0.650	90	800	60.842	183.324	131	85.150	85.179	0.785	1.461
93	0.200	0.650	0.650	105	1400	57.135	195.219	139	90.350	79.989	0.786	1.473
94	0.200	0.650	0.650	105	800	60.842	183.324	131	85.150	85.179	0.785	1.461
95	0.200	0.650	0.650	125	1400	57.135	195.219	139	90.350	79.989	0.786	1.473
96	0.200	0.650	0.650	125	800	60.842	183.324	131	85.150	85.179	0.785	1.461
97	0.200	0.700	0.580	70	1200	143.797	86.928	62	35.960	201.316	0.798	1.581
98	0.200	0.700	0.580	70	1000	145.902	85.674	61	35.380	204.263	0.798	1.576

99	0.200	0.700	0.580	70	800	148.219	84.335	60	34.800	207.506	0.797	1.571
100	0.200	0.700	0.580	90	1200	143.797	86.928	62	35.960	201.316	0.798	1.581
101	0.200	0.700	0.580	90	1000	145.902	85.674	61	35.380	204.263	0.798	1.576
102	0.200	0.700	0.580	90	800	148.219	84.335	60	34.800	207.506	0.797	1.571
103	0.200	0.700	0.580	105	1200	143.797	86.928	62	35.960	201.316	0.798	1.581
104	0.200	0.700	0.580	105	1000	145.902	85.674	61	35.380	204.263	0.798	1.576
105	0.200	0.700	0.580	105	800	148.219	84.335	60	34.800	207.506	0.797	1.571
106	0.200	0.700	0.580	125	1200	143.797	86.928	62	35.960	201.316	0.798	1.581
107	0.200	0.700	0.580	125	1000	145.902	85.674	61	35.380	204.263	0.798	1.576
108	0.200	0.700	0.580	125	800	148.219	84.335	60	34.800	207.506	0.797	1.571
109	0.200	0.700	0.600	70	1200	114.913	105.152	75	45.000	160.878	0.798	1.581
110	0.200	0.700	0.600	70	1000	116.746	103.501	74	44.400	163.444	0.798	1.576
111	0.200	0.700	0.600	70	800	118.771	101.736	73	43.800	166.279	0.797	1.571
112	0.200	0.700	0.600	90	1200	114.913	105.152	75	45.000	160.878	0.798	1.581
113	0.200	0.700	0.600	90	1000	116.746	103.501	74	44.400	163.444	0.798	1.576
114	0.200	0.700	0.600	90	800	118.771	101.736	73	43.800	166.279	0.797	1.571
115	0.200	0.700	0.600	105	1200	114.913	105.152	75	45.000	160.878	0.798	1.581
116	0.200	0.700	0.600	105	1000	116.746	103.501	74	44.400	163.444	0.798	1.576
117	0.200	0.700	0.600	105	800	118.771	101.736	73	43.800	166.279	0.797	1.571
118	0.200	0.700	0.600	125	1200	114.913	105.152	75	45.000	160.878	0.798	1.581
119	0.200	0.700	0.600	125	1000	116.746	103.501	74	44.400	163.444	0.798	1.576
120	0.200	0.700	0.600	125	800	118.771	101.736	73	43.800	166.279	0.797	1.571
121	0.200	0.700	0.625	70	1200	82.911	139.909	100	62.500	116.076	0.798	1.581
122	0.200	0.700	0.625	70	1000	84.425	137.400	98	61.250	118.195	0.798	1.576
123	0.200	0.700	0.625	70	800	86.107	134.716	96	60.000	120.550	0.797	1.571
124	0.200	0.700	0.625	90	1200	82.911	139.909	100	62.500	116.076	0.798	1.581
125	0.200	0.700	0.625	90	1000	84.425	137.400	98	61.250	118.195	0.798	1.576
126	0.200	0.700	0.625	90	800	86.107	134.716	96	60.000	120.550	0.797	1.571
127	0.200	0.700	0.625	105	1200	82.911	139.909	100	62.500	116.076	0.798	1.581
128	0.200	0.700	0.625	105	1000	84.425	137.400	98	61.250	118.195	0.798	1.576
129	0.200	0.700	0.625	105	800	86.107	134.716	96	60.000	120.550	0.797	1.571
130	0.200	0.700	0.625	125	1200	82.911	139.909	100	62.500	116.076	0.798	1.581
131	0.200	0.700	0.625	125	1000	84.425	137.400	98	61.250	118.195	0.798	1.576
132	0.200	0.700	0.625	125	800	86.107	134.716	96	60.000	120.550	0.797	1.571
133	0.200	0.700	0.650	70	1200	55.959	199.324	142	92.300	78.342	0.798	1.581
134	0.200	0.700	0.650	70	1000	57.160	195.135	139	90.350	80.023	0.798	1.576
135	0.200	0.700	0.650	70	800	58.501	190.660	136	88.400	81.902	0.797	1.571
136	0.200	0.700	0.650	90	1200	55.959	199.324	142	92.300	78.342	0.798	1.581
137	0.200	0.700	0.650	90	1000	57.160	195.135	139	90.350	80.023	0.798	1.576
138	0.200	0.700	0.650	90	800	58.501	190.660	136	88.400	81.902	0.797	1.571
139.000	0.200	0.700	0.650	105	1200	55.959	199.324	142	92.300	78.342	0.798	1.581
140.000	0.200	0.700	0.650	105	1000	57.160	195.135	139	90.350	80.023	0.798	1.576
141.000	0.200	0.700	0.650	105	800	58.501	190.660	136	88.400	81.902	0.797	1.571
142.000	0.200	0.700	0.650	125	1200	55.959	199.324	142	92.300	78.342	0.798	1.581
143.000	0.200	0.700	0.650	125	1000	57.160	195.135	139	90.350	80.023	0.798	1.576
144.000	0.200	0.700	0.650	125	800	58.501	190.660	136	88.400	81.902	0.797	1.571
145.000	0.150	0.600	0.580	70	1400	140.196	89.161	64	37.120	196.274	0.843	1.613
146.000	0.150	0.600	0.580	70	1200	141.800	88.152	63	36.540	198.520	0.844	1.617
147.000	0.150	0.600	0.580	70	1000	146.935	85.072	61	35.380	205.709	0.828	1.445
148.000	0.150	0.600	0.580	90	1400	140.196	89.161	64	37.120	196.274	0.843	1.613
149.000	0.150	0.600	0.580	90	1200	141.800	88.152	63	36.540	198.520	0.844	1.617
150.000	0.150	0.600	0.580	90	1000	146.935	85.072	61	35.380	205.709	0.828	1.445
151.000	0.150	0.600	0.580	105	1400	140.196	89.161	64	37.120	196.274	0.843	1.613
152.000	0.150	0.600	0.580	105	1200	141.800	88.152	63	36.540	198.520	0.844	1.617
153.000	0.150	0.600	0.580	105	1000	146.935	85.072	61	35.380	205.709	0.828	1.445
154.000	0.150	0.600	0.580	125	1400	140.196	89.161	64	37.120	196.274	0.843	1.613

155.000	0.150	0.600	0.580	125	1200	141.800	88.152	63	36.540	198.520	0.844	1.617
156.000	0.150	0.600	0.580	125	1000	146.935	85.072	61	35.380	205.709	0.828	1.445
157.000	0.150	0.600	0.600	70	1400	111.776	108.103	77	46.200	156.487	0.843	1.613
158.000	0.150	0.600	0.600	70	1200	113.150	106.790	76	45.600	158.410	0.844	1.617
159.000	0.150	0.600	0.600	70	1000	114.813	105.244	75	45.000	160.738	0.844	1.621
160.000	0.150	0.600	0.600	90	1400	111.776	108.103	77	46.200	156.487	0.843	1.613
161.000	0.150	0.600	0.600	90	1200	113.150	106.790	76	45.600	158.410	0.844	1.617
162.000	0.150	0.600	0.600	90	1000	114.813	105.244	75	45.000	160.738	0.844	1.621
163.000	0.150	0.600	0.600	105	1400	111.776	108.103	77	46.200	156.487	0.843	1.613
164.000	0.150	0.600	0.600	105	1200	113.150	106.790	76	45.600	158.410	0.844	1.617
165.000	0.150	0.600	0.600	125	1400	111.776	108.103	77	46.200	156.487	0.843	1.613
166.000	0.150	0.600	0.600	125	1200	113.150	106.790	76	45.600	158.410	0.844	1.617
167.000	0.150	0.600	0.600	125	1000	114.813	105.244	75	45.000	160.738	0.844	1.621
168.000	0.150	0.600	0.625	70	1400	80.322	144.418	103	64.375	112.451	0.843	1.613
169.000	0.150	0.600	0.625	70	1200	81.435	142.444	102	63.750	114.010	0.844	1.617
170.000	0.150	0.600	0.625	70	1000	82.790	140.114	100	62.500	115.905	0.844	1.621
171.000	0.150	0.600	0.625	90	1400	80.322	144.418	103	64.375	112.451	0.843	1.613
172.000	0.150	0.600	0.625	90	1200	81.435	142.444	102	63.750	114.010	0.844	1.617
173.000	0.150	0.600	0.625	90	1000	82.790	140.114	100	62.500	115.905	0.844	1.621
174.000	0.150	0.600	0.625	105	1400	80.322	144.418	103	64.375	112.451	0.843	1.613
175.000	0.150	0.600	0.625	105	1200	81.435	142.444	102	63.750	114.010	0.844	1.617
176.000	0.150	0.600	0.625	105	1000	82.790	140.114	100	62.500	115.905	0.844	1.621
177.000	0.150	0.600	0.625	125	1400	80.322	144.418	103	64.375	112.451	0.843	1.613
178.000	0.150	0.600	0.625	125	1200	81.435	142.444	102	63.750	114.010	0.844	1.617
179.000	0.150	0.600	0.625	125	1000	82.790	140.114	100	62.500	115.905	0.844	1.621
180.000	0.150	0.600	0.650	70	1400	53.911	206.894	148	96.200	75.475	0.843	1.613
181.000	0.150	0.600	0.650	70	1200	54.778	203.620	145	94.250	76.689	0.844	1.617
182.000	0.150	0.600	0.650	70	1000	55.838	199.754	143	92.950	78.173	0.844	1.621
183.000	0.150	0.600	0.650	90	1400	53.911	206.894	148	96.200	75.475	0.843	1.613
184.000	0.150	0.600	0.650	90	1200	54.778	203.620	145	94.250	76.689	0.844	1.617
185.000	0.150	0.600	0.650	90	1000	55.838	199.754	143	92.950	78.173	0.844	1.621
186.000	0.150	0.600	0.650	105	1400	53.911	206.894	148	96.200	75.475	0.843	1.613
187.000	0.150	0.600	0.650	105	1200	54.778	203.620	145	94.250	76.689	0.844	1.617
188.000	0.150	0.600	0.650	105	1000	55.838	199.754	143	92.950	78.173	0.844	1.621
189.000	0.150	0.600	0.650	125	1400	53.911	206.894	148	96.200	75.475	0.843	1.613
190.000	0.150	0.600	0.650	125	1200	54.778	203.620	145	94.250	76.689	0.844	1.617
191.000	0.150	0.600	0.650	125	1000	55.838	199.754	143	92.950	78.173	0.844	1.621
192.000	0.150	0.650	0.580	70	1400	136.847	91.343	65	37.700	191.585	0.854	1.752
193.000	0.150	0.650	0.580	70	1200	138.374	90.335	65	37.700	193.724	0.854	1.756
194.000	0.150	0.650	0.580	70	1000	140.195	89.162	64	37.120	196.273	0.854	1.759
195.000	0.150	0.650	0.580	70	800	142.176	87.919	63	36.540	199.047	0.855	1.763
196.000	0.150	0.650	0.580	90	1400	136.847	91.343	65	37.700	191.585	0.854	1.752
197.000	0.150	0.650	0.580	90	1200	138.374	90.335	65	37.700	193.724	0.854	1.756
198.000	0.150	0.650	0.580	90	1000	140.195	89.162	64	37.120	196.273	0.854	1.759
199.000	0.150	0.650	0.580	90	800	142.176	87.919	63	36.540	199.047	0.855	1.763
200.000	0.150	0.650	0.580	105	1400	136.847	91.343	65	37.700	191.585	0.854	1.752
201.000	0.150	0.650	0.580	105	1200	138.374	90.335	65	37.700	193.724	0.854	1.756
202.000	0.150	0.650	0.580	105	1000	140.195	89.162	64	37.120	196.273	0.854	1.759
203.000	0.150	0.650	0.580	105	800	142.176	87.919	63	36.540	199.047	0.855	1.763
204.000	0.150	0.650	0.580	125	1400	136.847	91.343	65	37.700	191.585	0.854	1.752
205.000	0.150	0.650	0.580	125	1200	138.374	90.335	65	37.700	193.724	0.854	1.756
206.000	0.150	0.650	0.580	125	1000	140.195	89.162	64	37.120	196.273	0.854	1.759
207.000	0.150	0.650	0.580	125	800	142.176	87.919	63	36.540	199.047	0.855	1.763
208.000	0.150	0.650	0.600	70	1400	108.645	111.219	79	47.400	152.103	0.854	1.752
209.000	0.150	0.650	0.600	70	1200	109.963	109.885	78	46.800	153.949	0.854	1.756
210.000	0.150	0.650	0.600	70	1000	111.541	108.331	77	46.200	156.158	0.854	1.759

211.000	0.150	0.650	0.600	70	800	113.267	106.680	76	45.600	158.574	0.855	1.763
212.000	0.150	0.650	0.600	90	1400	108.645	111.219	79	47.400	152.103	0.854	1.752
213.000	0.150	0.650	0.600	90	1200	109.963	109.885	78	46.800	153.949	0.854	1.756
214.000	0.150	0.650	0.600	90	1000	111.541	108.331	77	46.200	156.158	0.854	1.759
215.000	0.150	0.650	0.600	90	800	113.267	106.680	76	45.600	158.574	0.855	1.763
216.000	0.150	0.650	0.600	105	1400	108.645	111.219	79	47.400	152.103	0.854	1.752
217.000	0.150	0.650	0.600	105	1200	109.963	109.885	78	46.800	153.949	0.854	1.756
218.000	0.150	0.650	0.600	105	1000	111.541	108.331	77	46.200	156.158	0.854	1.759
219.000	0.150	0.650	0.600	105	800	113.267	106.680	76	45.600	158.574	0.855	1.763
220.000	0.150	0.650	0.600	125	1400	108.645	111.219	79	47.400	152.103	0.854	1.752
221.000	0.150	0.650	0.600	125	1200	109.963	109.885	78	46.800	153.949	0.854	1.756
222.000	0.150	0.650	0.600	125	1000	111.541	108.331	77	46.200	156.158	0.854	1.759
223.000	0.150	0.650	0.600	125	800	113.267	106.680	76	45.600	158.574	0.855	1.763
224.000	0.150	0.650	0.625	70	1400	77.555	149.571	107	66.875	108.577	0.854	1.752
225.000	0.150	0.650	0.625	70	1200	78.631	147.525	105	65.625	110.083	0.854	1.756
226.000	0.150	0.650	0.625	70	1000	79.924	145.137	104	65.000	111.894	0.854	1.759
227.000	0.150	0.650	0.625	70	800	81.348	142.597	102	63.750	113.887	0.855	1.763
228.000	0.150	0.650	0.625	90	1400	77.555	149.571	107	66.875	108.577	0.854	1.752
229.000	0.150	0.650	0.625	90	1200	78.631	147.525	105	65.625	110.083	0.854	1.756
230.000	0.150	0.650	0.625	90	1000	79.924	145.137	104	65.000	111.894	0.854	1.759
231.000	0.150	0.650	0.625	90	800	81.348	142.597	102	63.750	113.887	0.855	1.763
232.000	0.150	0.650	0.625	105	1400	77.555	149.571	107	66.875	108.577	0.854	1.752
233.000	0.150	0.650	0.625	105	1200	78.631	147.525	105	65.625	110.083	0.854	1.756
234.000	0.150	0.650	0.625	105	1000	79.924	145.137	104	65.000	111.894	0.854	1.759
235.000	0.150	0.650	0.625	105	800	81.348	142.597	102	63.750	113.887	0.855	1.763
236.000	0.150	0.650	0.625	125	1400	77.555	149.571	107	66.875	108.577	0.854	1.752
237.000	0.150	0.650	0.625	125	1200	78.631	147.525	105	65.625	110.083	0.854	1.756
238.000	0.150	0.650	0.625	125	1000	79.924	145.137	104	65.000	111.894	0.854	1.759
239.000	0.150	0.650	0.625	125	800	81.348	142.597	102	63.750	113.887	0.855	1.763
240.000	0.150	0.650	0.650	70	1400	51.617	216.089	154	100.100	72.264	0.854	1.752
241.000	0.150	0.650	0.650	70	1200	52.456	212.631	152	98.800	73.439	0.854	1.756
242.000	0.150	0.650	0.650	70	1000	53.471	208.597	149	96.850	74.859	0.854	1.759
243.000	0.150	0.650	0.650	70	800	54.595	204.304	146	94.900	76.432	0.855	1.763
244.000	0.150	0.650	0.650	90	1400	51.617	216.089	154	100.100	72.264	0.854	1.752
245.000	0.150	0.650	0.650	90	1200	52.456	212.631	152	98.800	73.439	0.854	1.756
246.000	0.150	0.650	0.650	90	1000	53.471	208.597	149	96.850	74.859	0.854	1.759
247.000	0.150	0.650	0.650	90	800	54.595	204.304	146	94.900	76.432	0.855	1.763
248.000	0.150	0.650	0.650	105	1400	51.617	216.089	154	100.100	72.264	0.854	1.752
249.000	0.150	0.650	0.650	105	1200	52.456	212.631	152	98.800	73.439	0.854	1.756
250.000	0.150	0.650	0.650	105	1000	53.471	208.597	149	96.850	74.859	0.854	1.759
251.000	0.150	0.650	0.650	105	800	54.595	204.304	146	94.900	76.432	0.855	1.763
252.000	0.150	0.650	0.650	125	1400	51.617	216.089	154	100.100	72.264	0.854	1.752
253.000	0.150	0.650	0.650	125	1200	52.456	212.631	152	98.800	73.439	0.854	1.756
254.000	0.150	0.650	0.650	125	1000	53.471	208.597	149	96.850	74.859	0.854	1.759
255.000	0.150	0.650	0.650	125	800	54.595	204.304	146	94.900	76.432	0.855	1.763
256.000	0.150	0.700	0.580	70	1200	134.967	92.616	66	38.280	188.953	0.863	1.893
257.000	0.150	0.700	0.580	70	1000	136.690	91.448	65	37.700	191.365	0.863	1.897
258.000	0.150	0.700	0.580	70	800	138.534	90.231	64	37.120	193.947	0.864	1.900
259.000	0.150	0.700	0.580	90	1200	134.967	92.616	66	38.280	188.953	0.863	1.893
260.000	0.150	0.700	0.580	90	1000	136.690	91.448	65	37.700	191.365	0.863	1.897
261.000	0.150	0.700	0.580	90	800	138.534	90.231	64	37.120	193.947	0.864	1.900
262.000	0.150	0.700	0.580	105	1200	134.967	92.616	66	38.280	188.953	0.863	1.893
263.000	0.150	0.700	0.580	105	1000	136.690	91.448	65	37.700	191.365	0.863	1.897
264.000	0.150	0.700	0.580	105	800	138.534	90.231	64	37.120	193.947	0.864	1.900
265.000	0.150	0.700	0.580	125	1200	134.967	92.616	66	38.280	188.953	0.863	1.893
266.000	0.150	0.700	0.580	125	1000	136.690	91.448	65	37.700	191.365	0.863	1.897

267.000	0.150	0.700	0.580	125	800	138.534	90.231	64	37.120	193.947	0.864	1.900
268.000	0.150	0.700	0.600	70	1200	106.825	113.113	81	48.600	149.555	0.863	1.893
269.000	0.150	0.700	0.600	70	1000	108.327	111.545	80	48.000	151.658	0.863	1.897
270.000	0.150	0.700	0.600	70	800	109.941	109.907	79	47.400	153.918	0.864	1.900
271.000	0.150	0.700	0.600	90	1200	106.825	113.113	81	48.600	149.555	0.863	1.893
272.000	0.150	0.700	0.600	90	1000	108.327	111.545	80	48.000	151.658	0.863	1.897
273.000	0.150	0.700	0.600	90	800	109.941	109.907	79	47.400	153.918	0.864	1.900
274.000	0.150	0.700	0.600	105	1200	106.825	113.113	81	48.600	149.555	0.863	1.893
275.000	0.150	0.700	0.600	105	1000	108.327	111.545	80	48.000	151.658	0.863	1.897
276.000	0.150	0.700	0.600	105	800	109.941	109.907	79	47.400	153.918	0.864	1.900
277.000	0.150	0.700	0.600	125	1200	106.825	113.113	81	48.600	149.555	0.863	1.893
278.000	0.150	0.700	0.600	125	1000	108.327	111.545	80	48.000	151.658	0.863	1.897
279.000	0.150	0.700	0.600	125	800	109.941	109.907	79	47.400	153.918	0.864	1.900
280.000	0.150	0.700	0.625	70	1200	75.902	152.829	109	68.125	106.262	0.863	1.893
281.000	0.150	0.700	0.625	70	1000	77.138	150.381	107	66.875	107.993	0.863	1.897
282.000	0.150	0.700	0.625	70	800	78.474	147.820	106	66.250	109.864	0.864	1.900
283.000	0.150	0.700	0.625	90	1200	75.902	152.829	109	68.125	106.262	0.863	1.893
284.000	0.150	0.700	0.625	90	1000	77.138	150.380	107	66.875	107.993	0.863	1.897
285.000	0.150	0.700	0.625	90	800	78.474	147.820	106	66.250	109.864	0.864	1.900
286.000	0.150	0.700	0.625	105	1200	75.902	152.829	109	68.125	106.262	0.863	1.893
287.000	0.150	0.700	0.625	105	1000	77.138	150.380	107	66.875	107.993	0.863	1.897
288.000	0.150	0.700	0.625	105	800	78.474	147.820	106	66.250	109.864	0.864	1.900
289.000	0.150	0.700	0.625	125	1200	75.902	152.829	109	68.125	106.262	0.863	1.893
290.000	0.150	0.700	0.625	125	1000	77.138	150.380	107	66.875	107.993	0.863	1.897
291.000	0.150	0.700	0.625	125	800	78.474	147.820	106	66.250	109.864	0.864	1.900
292.000	0.150	0.700	0.650	70	1200	50.226	222.072	159	103.350	70.317	0.863	1.893
293.000	0.150	0.700	0.650	70	1000	51.195	217.870	156	101.400	71.673	0.863	1.897
294.000	0.150	0.700	0.650	70	800	52.248	213.478	152	98.800	73.148	0.864	1.900
295.000	0.150	0.700	0.650	90	1200	50.226	222.072	159	103.350	70.317	0.863	1.893
296.000	0.150	0.700	0.650	90	1000	51.195	217.870	156	101.400	71.673	0.863	1.897
297.000	0.150	0.700	0.650	90	800	52.248	213.478	152	98.800	73.148	0.864	1.900
298.000	0.150	0.700	0.650	105	1200	50.226	222.072	159	103.350	70.317	0.863	1.893
299.000	0.150	0.700	0.650	105	1000	51.195	217.870	156	101.400	71.673	0.863	1.897
300.000	0.150	0.700	0.650	105	800	52.248	213.478	152	98.800	73.148	0.864	1.900
301.000	0.150	0.700	0.650	125	1200	50.226	222.072	159	103.350	70.317	0.863	1.893
302.000	0.150	0.700	0.650	125	1000	51.195	217.870	156	101.400	71.673	0.863	1.897
303.000	0.150	0.700	0.650	125	800	52.248	213.478	152	98.800	73.148	0.864	1.900
304.000	0.100	0.600	0.580	70	1400	133.709	93.487	67	38.860	187.193	0.893	1.670
305.000	0.100	0.600	0.580	70	1200	135.233	92.433	66	38.280	189.326	0.893	1.674
306.000	0.100	0.600	0.580	70	1000	137.089	91.182	65	37.700	191.924	0.894	1.679
307.000	0.100	0.600	0.580	70	800	139.172	89.817	64	37.120	194.841	0.894	1.684
308.000	0.100	0.600	0.580	90	1400	133.709	93.487	67	38.860	187.193	0.893	1.670
309.000	0.100	0.600	0.580	90	1200	135.233	92.433	66	38.280	189.326	0.893	1.674
310.000	0.100	0.600	0.580	90	1000	137.089	91.182	65	37.700	191.924	0.894	1.679
311.000	0.100	0.600	0.580	90	800	139.172	89.817	64	37.120	194.841	0.894	1.684
312.000	0.100	0.600	0.580	105	1400	133.709	93.487	67	38.860	187.193	0.893	1.670
313.000	0.100	0.600	0.580	105	1200	135.233	92.433	66	38.280	189.326	0.893	1.674
314.000	0.100	0.600	0.580	105	1000	137.089	91.182	65	37.700	191.924	0.894	1.679
315.000	0.100	0.600	0.580	105	800	139.172	89.817	64	37.120	194.841	0.894	1.684
316.000	0.100	0.600	0.580	125	1400	133.709	93.487	67	38.860	187.193	0.893	1.670
317.000	0.100	0.600	0.580	125	1200	135.233	92.433	66	38.280	189.326	0.893	1.674
318.000	0.100	0.600	0.580	125	1000	137.089	91.182	65	37.700	191.924	0.894	1.679
319.000	0.100	0.600	0.580	125	800	139.172	89.817	64	37.120	194.841	0.894	1.684
320.000	0.100	0.600	0.600	70	1400	105.952	114.046	81	48.600	148.332	0.893	1.670
321.000	0.100	0.600	0.600	70	1200	107.247	112.669	80	48.000	150.145	0.893	1.674
322.000	0.100	0.600	0.600	70	1000	108.831	111.029	79	47.400	152.363	0.894	1.679

323.000	0.100	0.600	0.600	70	800	110.620	109.233	78	46.800	154.868	0.894	1.684
324.000	0.100	0.600	0.600	90	1400	105.952	114.046	81	48.600	148.332	0.893	1.670
325.000	0.100	0.600	0.600	90	1200	107.247	112.669	80	48.000	150.145	0.893	1.674
326.000	0.100	0.600	0.600	90	1000	108.831	111.029	79	47.400	152.363	0.894	1.679
327.000	0.100	0.600	0.600	90	800	110.620	109.233	78	46.800	154.868	0.894	1.684
328.000	0.100	0.600	0.600	105	1400	105.952	114.046	81	48.600	148.332	0.893	1.670
329.000	0.100	0.600	0.600	105	1200	107.247	112.669	80	48.000	150.145	0.893	1.674
330.000	0.100	0.600	0.600	105	1000	108.831	111.029	79	47.400	152.363	0.894	1.679
331.000	0.100	0.600	0.600	105	800	110.620	109.233	78	46.800	154.868	0.894	1.684
332.000	0.100	0.600	0.600	125	1400	105.952	114.046	81	48.600	148.332	0.893	1.670
333.000	0.100	0.600	0.600	125	1200	107.247	112.669	80	48.000	150.145	0.893	1.674
334.000	0.100	0.600	0.600	125	1000	108.831	111.029	79	47.400	152.363	0.894	1.679
335.000	0.100	0.600	0.600	125	800	110.620	109.233	78	46.800	154.868	0.894	1.684
336.000	0.100	0.600	0.625	70	1400	75.374	153.900	110	68.750	105.523	0.893	1.670
337.000	0.100	0.600	0.625	70	1200	76.411	151.811	108	67.500	106.976	0.893	1.674
338.000	0.100	0.600	0.625	70	1000	77.687	149.317	107	66.875	108.762	0.894	1.679
339.000	0.100	0.600	0.625	70	800	79.139	146.577	105	65.625	110.795	0.894	1.684
340.000	0.100	0.600	0.625	90	1400	75.374	153.900	110	68.750	105.523	0.893	1.670
341.000	0.100	0.600	0.625	90	1200	76.411	151.811	108	67.500	106.976	0.893	1.674
342.000	0.100	0.600	0.625	90	1000	77.687	149.317	107	66.875	108.762	0.894	1.679
343.000	0.100	0.600	0.625	90	800	79.139	146.577	105	65.625	110.795	0.894	1.684
344.000	0.100	0.600	0.625	105	1400	75.374	153.900	110	68.750	105.523	0.893	1.670
345.000	0.100	0.600	0.625	105	1200	76.411	151.811	108	67.500	106.976	0.893	1.674
346.000	0.100	0.600	0.625	105	1000	77.687	149.317	107	66.875	108.762	0.894	1.679
347.000	0.100	0.600	0.625	105	800	79.139	146.577	105	65.625	110.795	0.894	1.684
348.000	0.100	0.600	0.625	125	1400	75.374	153.900	110	68.750	105.523	0.893	1.670
349.000	0.100	0.600	0.625	125	1200	76.411	151.811	108	67.500	106.976	0.893	1.674
350.000	0.100	0.600	0.625	125	1000	77.687	149.317	107	66.875	108.762	0.894	1.679
351.000	0.100	0.600	0.625	125	800	79.139	146.577	105	65.625	110.795	0.894	1.684
352.000	0.100	0.600	0.650	70	1400	49.928	223.397	160	104.000	69.900	0.893	1.670
353.000	0.100	0.600	0.650	70	1200	50.724	219.894	157	102.050	71.013	0.893	1.674
354.000	0.100	0.600	0.650	70	1000	51.708	215.710	154	100.100	72.391	0.894	1.679
355.000	0.100	0.600	0.650	70	800	52.836	211.103	151	98.150	73.970	0.894	1.684
356.000	0.100	0.600	0.650	90	1400	49.928	223.397	160	104.000	69.900	0.893	1.670
357.000	0.100	0.600	0.650	90	1200	50.724	219.894	157	102.050	71.013	0.893	1.674
358.000	0.100	0.600	0.650	90	1000	51.708	215.710	154	100.100	72.391	0.894	1.679
359.000	0.100	0.600	0.650	90	800	52.836	211.103	151	98.150	73.970	0.894	1.684
360.000	0.100	0.600	0.650	105	1400	49.928	223.397	160	104.000	69.900	0.893	1.670
361.000	0.100	0.600	0.650	105	1200	50.724	219.894	157	102.050	71.013	0.893	1.674
362.000	0.100	0.600	0.650	105	1000	51.708	215.710	154	100.100	72.391	0.894	1.679
363.000	0.100	0.600	0.650	105	800	52.836	211.103	151	98.150	73.970	0.894	1.684
364.000	0.100	0.600	0.650	125	1400	49.928	223.397	160	104.000	69.900	0.893	1.670
365.000	0.100	0.600	0.650	125	1200	50.724	219.894	157	102.050	71.013	0.893	1.674
366.000	0.100	0.600	0.650	125	1000	51.708	215.710	154	100.100	72.391	0.894	1.679
367.000	0.100	0.600	0.650	125	800	52.836	211.103	151	98.150	73.970	0.894	1.684
368.000	0.100	0.650	0.580	70	1400	130.445	95.826	68	39.440	182.623	0.901	1.814
369.000	0.100	0.650	0.580	70	1200	131.895	94.773	68	39.440	184.653	0.901	1.818
370.000	0.100	0.650	0.580	70	1000	133.640	93.535	67	38.860	187.096	0.901	1.823
371.000	0.100	0.650	0.580	70	800	135.562	92.209	66	38.280	189.786	0.901	1.827
372.000	0.100	0.650	0.580	90	1400	130.445	95.826	68	39.440	182.623	0.901	1.814
373.000	0.100	0.650	0.580	90	1200	131.895	94.773	68	39.440	184.653	0.901	1.818
374.000	0.100	0.650	0.580	90	1000	133.640	93.535	67	38.860	187.096	0.901	1.823
375.000	0.100	0.650	0.580	90	800	135.562	92.209	66	38.280	189.786	0.901	1.827
376.000	0.100	0.650	0.580	105	1400	130.445	95.826	68	39.440	182.623	0.901	1.814
377.000	0.100	0.650	0.580	105	1200	131.895	94.773	68	39.440	184.653	0.901	1.818
378.000	0.100	0.650	0.580	105	1000	133.640	93.535	67	38.860	187.096	0.901	1.823

379.000	0.100	0.650	0.580	105	800	135.562	92.209	66	38.280	189.786	0.901	1.827
380.000	0.100	0.650	0.580	125	1400	130.445	95.826	68	39.440	182.623	0.901	1.814
381.000	0.100	0.650	0.580	125	1200	131.895	94.773	68	39.440	184.653	0.901	1.818
382.000	0.100	0.650	0.580	125	1000	133.640	93.535	67	38.860	187.096	0.901	1.823
383.000	0.100	0.650	0.580	125	800	135.562	92.209	66	38.280	189.786	0.901	1.827
384.000	0.100	0.650	0.600	70	1400	102.899	117.429	84	50.400	144.059	0.901	1.814
385.000	0.100	0.650	0.600	70	1200	104.142	116.028	83	49.800	145.799	0.901	1.818
386.000	0.100	0.650	0.600	70	1000	105.645	114.377	82	49.200	147.902	0.901	1.823
387.000	0.100	0.650	0.600	70	800	107.308	112.604	80	48.000	150.231	0.901	1.827
388.000	0.100	0.650	0.600	90	1400	102.899	117.429	84	50.400	144.059	0.901	1.814
389.000	0.100	0.650	0.600	90	1200	104.142	116.028	83	49.800	145.799	0.901	1.818
390.000	0.100	0.650	0.600	90	1000	105.645	114.377	82	49.200	147.902	0.901	1.823
391.000	0.100	0.650	0.600	90	800	107.308	112.604	80	48.000	150.231	0.901	1.827
392.000	0.100	0.650	0.600	105	1400	102.899	117.429	84	50.400	144.059	0.901	1.814
393.000	0.100	0.650	0.600	105	1200	104.142	116.028	83	49.800	145.799	0.901	1.818
394.000	0.100	0.650	0.600	105	1000	105.645	114.377	82	49.200	147.902	0.901	1.823
395.000	0.100	0.650	0.600	105	800	107.308	112.604	80	48.000	150.231	0.901	1.827
396.000	0.100	0.650	0.600	125	1400	102.899	117.429	84	50.400	144.059	0.901	1.814
397.000	0.100	0.650	0.600	125	1200	104.142	116.028	83	49.800	145.799	0.901	1.818
398.000	0.100	0.650	0.600	125	1000	105.645	114.377	82	49.200	147.902	0.901	1.823
399.000	0.100	0.650	0.600	125	800	107.308	112.604	80	48.000	150.231	0.901	1.827
400.000	0.100	0.650	0.625	70	1400	72.687	159.589	114	71.250	101.761	0.901	1.814
401.000	0.100	0.650	0.625	70	1200	73.690	157.416	112	70.000	103.166	0.901	1.818
402.000	0.100	0.650	0.625	70	1000	74.909	154.854	111	69.375	104.873	0.901	1.823
403.000	0.100	0.650	0.625	70	800	76.268	152.094	109	68.125	106.776	0.901	1.827
404.000	0.100	0.650	0.625	90	1400	72.687	159.589	114	71.250	101.761	0.901	1.814
405.000	0.100	0.650	0.625	90	1200	73.690	157.416	112	70.000	103.166	0.901	1.818
406.000	0.100	0.650	0.625	90	1000	74.909	154.854	111	69.375	104.873	0.901	1.823
407.000	0.100	0.650	0.625	90	800	76.268	152.094	109	68.125	106.776	0.901	1.827
408.000	0.100	0.650	0.625	105	1400	72.687	159.589	114	71.250	101.761	0.901	1.814
409.000	0.100	0.650	0.625	105	1200	73.690	157.416	112	70.000	103.166	0.901	1.818
410.000	0.100	0.650	0.625	105	1000	74.909	154.854	111	69.375	104.873	0.901	1.823
411.000	0.100	0.650	0.625	105	800	76.268	152.094	109	68.125	106.776	0.901	1.827
412.000	0.100	0.650	0.625	125	1400	72.687	159.589	114	71.250	101.761	0.901	1.814
413.000	0.100	0.650	0.625	125	1200	73.690	157.416	112	70.000	103.166	0.901	1.818
414.000	0.100	0.650	0.625	125	1000	74.909	154.854	111	69.375	104.873	0.901	1.823
415.000	0.100	0.650	0.625	125	800	76.268	152.094	109	68.125	106.776	0.901	1.827
416.000	0.100	0.650	0.650	70	1400	47.725	233.711	167	108.550	66.815	0.901	1.814
417.000	0.100	0.650	0.650	70	1200	48.496	229.997	164	106.600	67.894	0.901	1.818
418.000	0.100	0.650	0.650	70	1000	49.438	225.615	161	104.650	69.213	0.901	1.823
419.000	0.100	0.650	0.650	70	800	50.495	220.890	158	102.700	70.693	0.901	1.827
420.000	0.100	0.650	0.650	90	1400	47.725	233.711	167	108.550	66.815	0.901	1.814
421.000	0.100	0.650	0.650	90	1200	48.496	229.997	164	106.600	67.894	0.901	1.818
422.000	0.100	0.650	0.650	90	1000	49.438	225.615	161	104.650	69.213	0.901	1.823
423.000	0.100	0.650	0.650	90	800	50.495	220.890	158	102.700	70.693	0.901	1.827
424.000	0.100	0.650	0.650	105	1400	47.725	233.711	167	108.550	66.815	0.901	1.814
425.000	0.100	0.650	0.650	105	1200	48.496	229.997	164	106.600	67.894	0.901	1.818
426.000	0.100	0.650	0.650	105	1000	49.438	225.615	161	104.650	69.213	0.901	1.823
427.000	0.100	0.650	0.650	105	800	50.495	220.890	158	102.700	70.693	0.901	1.827
428.000	0.100	0.650	0.650	125	1400	47.725	233.711	167	108.550	66.815	0.901	1.814
429.000	0.100	0.650	0.650	125	1200	48.496	229.997	164	106.600	67.894	0.901	1.818
430.000	0.100	0.650	0.650	125	1000	49.438	225.615	161	104.650	69.213	0.901	1.823
431.000	0.100	0.650	0.650	125	800	50.495	220.890	158	102.700	70.693	0.901	1.827
432.000	0.100	0.700	0.580	70	1200	128.567	97.225	69	40.020	179.994	0.907	1.962
433.000	0.100	0.700	0.580	70	1000	130.217	95.994	69	40.020	182.304	0.908	1.965

604162.WKS
THIS FILE IS FOR USE IN CONJUCTION WITH 604162.PRN FILES
COMMON PARAMETERS

PNET	5.000 KW		EFFICIENCY	
PGROSS	7.250 KW		MECH	0.862
PARASITE	0.800 KW		INV	0.800

TCELL 375.000 DEGF
BURN ENR 1.200

	EFFICIENCY					FLOW RATES ACFM(NODE)				
CASE	OVERALL	STACK	FUEL PROC	HX AREA HX1	HX AREA HX2	ACFM4	ACFM9	ACFM11	ACFM12	Q(5) BTU/HR
1	0.184	0.463	0.577	1.194	12.062	54.321	95.782	83.688	273.549	6813.653
2	0.184	0.463	0.575	0.856	12.197	48.664	93.114	83.688	273.549	5415.262
3	0.182	0.463	0.571	0.503	10.269	42.998	89.726	83.688	273.549	4084.750
4	0.181	0.463	0.567	0.317	10.954	37.294	85.701	83.688	273.549	2643.035
5	0.184	0.463	0.577	1.194	12.062	54.321	95.782	92.940	273.549	6813.653
6	0.184	0.463	0.575	0.856	12.197	48.664	93.114	92.940	273.549	5415.262
7	0.182	0.463	0.571	0.503	10.269	42.998	89.726	92.940	273.549	4084.750
8	0.181	0.463	0.567	0.317	10.954	37.294	85.701	92.940	273.549	2643.035
9	0.184	0.463	0.577	1.194	12.062	54.321	95.782	100.779	273.549	6813.653
10	0.184	0.463	0.575	0.856	12.197	48.664	93.114	100.779	273.549	5415.262
11	0.182	0.463	0.571	0.503	10.269	42.998	89.726	100.779	273.549	4084.750
12	0.181	0.463	0.567	0.317	10.954	37.294	85.701	100.779	273.549	2643.035
13	0.184	0.463	0.577	1.194	12.062	54.321	95.782	112.694	273.549	6813.653
14	0.184	0.463	0.575	0.856	12.197	48.664	93.114	112.694	273.549	5415.262
15	0.182	0.463	0.571	0.503	10.269	42.998	89.726	112.694	273.549	4084.750
16	0.181	0.463	0.567	0.317	10.954	37.294	85.701	112.694	273.549	2643.035
17	0.191	0.479	0.577	1.155	11.660	52.510	92.589	78.493	256.569	6586.496
18	0.190	0.479	0.575	0.827	11.793	47.042	90.010	78.493	256.569	5234.711
19	0.189	0.479	0.571	0.487	9.867	41.565	86.735	78.493	256.569	3950.953
20	0.187	0.479	0.567	0.307	10.553	36.051	82.845	78.493	256.569	2555.664
21	0.191	0.479	0.577	1.155	11.660	52.510	92.589	87.171	256.569	6586.496
22	0.190	0.479	0.575	0.827	11.793	47.042	90.010	87.171	256.569	5234.711
23	0.189	0.479	0.571	0.487	9.867	41.565	86.735	87.171	256.569	3950.953
24	0.187	0.479	0.567	0.307	10.553	36.051	82.845	87.171	256.569	2555.664
25	0.191	0.479	0.577	1.155	11.660	52.510	92.589	94.524	256.569	6586.496
26	0.190	0.479	0.575	0.827	11.793	47.042	90.010	94.524	256.569	5234.711
27	0.189	0.479	0.571	0.487	9.867	41.565	86.735	94.524	256.569	3950.953
28	0.187	0.479	0.567	0.307	10.553	36.051	82.845	94.524	256.569	2555.664
29	0.191	0.479	0.577	1.155	11.660	52.510	92.589	105.699	256.569	6586.496
30	0.190	0.479	0.575	0.827	11.793	47.042	90.010	105.699	256.569	5234.711
31	0.189	0.479	0.571	0.487	9.867	41.565	86.735	105.699	256.569	3950.953
32	0.187	0.479	0.567	0.307	10.553	36.051	82.845	105.699	256.569	2555.664
33	0.199	0.499	0.577	1.108	11.194	50.410	88.885	72.467	236.872	6323.031
34	0.198	0.499	0.575	0.794	11.320	45.160	86.409	72.467	236.872	5025.309
35	0.197	0.499	0.571	0.468	9.508	39.902	83.266	72.467	236.872	3791.496
36	0.195	0.499	0.567	0.294	10.107	34.609	79.531	72.467	236.872	2453.914
37	0.199	0.499	0.577	1.108	11.194	50.410	88.885	80.479	236.872	6323.031
38	0.198	0.499	0.575	0.794	11.320	45.160	86.409	80.479	236.872	5025.309
39	0.197	0.499	0.571	0.468	9.508	39.902	83.266	80.479	236.872	3791.496
40	0.195	0.499	0.567	0.294	10.107	34.609	79.531	80.479	236.872	2453.914
41	0.199	0.499	0.577	1.108	11.194	50.410	88.885	87.267	236.872	6323.031
42	0.198	0.499	0.575	0.794	11.320	45.160	86.409	87.267	236.872	5025.309

43	0.197	0.499	0.571	0.468	9.508	39.902	83.266	87.267	236.872	3791.496
44	0.195	0.499	0.567	0.294	10.107	34.609	79.531	87.267	236.872	2453.914
45	0.199	0.499	0.577	1.108	11.194	50.410	88.885	97.585	236.872	6323.031
46	0.198	0.499	0.575	0.794	11.320	45.160	86.409	97.585	236.872	5025.309
47	0.197	0.499	0.571	0.468	9.508	39.902	83.266	97.585	236.872	3791.496
48	0.195	0.499	0.567	0.294	10.107	34.609	79.531	97.585	236.872	2453.914
49	0.207	0.519	0.577	1.066	10.763	48.471	85.467	66.905	218.690	6079.856
50	0.206	0.519	0.575	0.764	10.884	43.423	83.086	66.905	218.690	4832.055
51	0.204	0.519	0.571	0.449	9.138	38.368	80.063	66.905	218.690	3645.840
52	0.203	0.519	0.567	0.283	9.750	33.278	76.472	66.905	218.690	2358.883
53	0.207	0.519	0.577	1.066	10.763	48.471	85.467	74.302	218.690	6079.856
54	0.206	0.519	0.575	0.764	10.884	43.423	83.086	74.302	218.690	4832.055
55	0.204	0.519	0.571	0.449	9.138	38.368	80.063	74.302	218.690	3645.840
56	0.203	0.519	0.567	0.283	9.750	33.278	76.472	74.302	218.690	2358.883
57	0.207	0.519	0.577	1.066	10.763	48.471	85.467	80.569	218.690	6079.856
58	0.206	0.519	0.575	0.764	10.884	43.423	83.086	80.569	218.690	4832.055
59	0.204	0.519	0.571	0.449	9.138	38.368	80.063	80.569	218.690	3645.840
60	0.203	0.519	0.567	0.283	9.750	33.278	76.472	80.569	218.690	2358.883
61	0.207	0.519	0.577	1.066	10.763	48.471	85.467	90.094	218.690	6079.856
62	0.206	0.519	0.575	0.764	10.884	43.423	83.086	90.094	218.690	4832.055
63	0.204	0.519	0.571	0.449	9.138	38.368	80.063	90.094	218.690	3645.840
64	0.203	0.519	0.567	0.283	9.750	33.278	76.472	90.094	218.690	2358.883
65	0.199	0.463	0.623	1.248	11.961	52.469	84.102	83.688	273.549	6329.656
66	0.196	0.463	0.613	0.329	10.392	35.961	73.794	83.688	273.549	2452.801
67	0.199	0.463	0.623	1.248	11.961	52.469	84.102	92.940	273.549	6329.656
68	0.196	0.463	0.613	0.329	10.392	35.961	73.794	92.940	273.549	2452.801
69	0.199	0.463	0.623	1.248	11.961	52.469	84.102	100.779	273.549	6329.656
70	0.196	0.463	0.613	0.329	10.392	35.961	73.794	100.779	273.549	2452.801
71	0.199	0.463	0.623	1.248	11.961	52.469	84.102	112.694	273.549	6329.656
72	0.196	0.463	0.613	0.329	10.392	35.961	73.794	112.694	273.549	2452.801
73	0.206	0.479	0.623	1.206	11.562	50.720	81.299	78.493	256.569	6118.672
74	0.202	0.479	0.613	0.319	9.842	34.762	71.335	78.493	256.569	2376.223
75	0.206	0.479	0.623	1.206	11.562	50.720	81.299	87.171	256.569	6118.672
76	0.202	0.479	0.613	0.319	9.842	34.762	71.335	87.171	256.569	2376.223
77	0.206	0.479	0.623	1.206	11.562	50.720	81.299	94.524	256.569	6118.672
78	0.202	0.479	0.613	0.319	9.842	34.762	71.335	94.524	256.569	2376.223
79	0.206	0.479	0.623	1.206	11.562	50.720	81.299	105.699	256.569	6118.672
80	0.202	0.479	0.613	0.319	9.842	34.762	71.335	105.699	256.569	2376.223
81	0.214	0.499	0.623	1.158	11.100	48.692	78.047	72.467	236.872	5873.946
82	0.211	0.499	0.613	0.305	9.582	33.372	68.481	72.467	236.872	2277.738
83	0.214	0.499	0.623	1.158	11.100	48.692	78.047	80.479	236.872	5673.946
84	0.211	0.499	0.613	0.305	9.582	33.372	68.481	80.479	236.872	2277.738
85	0.214	0.499	0.623	1.158	11.100	48.692	78.047	87.267	236.872	5873.946
86	0.211	0.499	0.613	0.305	9.582	33.372	68.481	87.267	236.872	2277.738
87	0.214	0.499	0.623	1.158	11.100	48.692	78.047	97.585	236.872	5873.946
88	0.211	0.499	0.613	0.305	9.582	33.372	68.481	97.585	236.872	2277.738
89	0.223	0.519	0.623	1.113	10.673	46.819	75.045	66.905	218.690	5648.008
90	0.219	0.519	0.613	0.294	9.107	32.088	65.847	66.905	218.690	2192.867
91	0.223	0.519	0.623	1.113	10.673	46.819	75.045	74.302	218.690	5648.008
92	0.219	0.519	0.613	0.294	9.107	32.088	65.847	74.302	218.690	2192.867
93	0.223	0.519	0.623	1.113	10.673	46.819	75.045	80.569	218.690	5648.008
94	0.219	0.519	0.613	0.294	9.107	32.088	65.847	80.569	218.690	2192.867
95	0.223	0.519	0.623	1.113	10.673	46.819	75.045	90.094	218.690	5648.008
96	0.219	0.519	0.613	0.294	9.107	32.088	65.847	90.094	218.690	2192.867
97	0.212	0.463	0.665	0.991	11.404	45.531	71.108	83.688	273.549	4710.567
98	0.211	0.463	0.662	0.659	11.710	40.185	67.550	83.688	273.549	3482.008

99	0.210	0.463	0.658	0.416	11.051	34.803	63.473	83.688	273.549	2262.317
100	0.212	0.463	0.665	0.991	11.404	45.531	71.108	92.940	273.549	4710.567
101	0.211	0.463	0.662	0.659	11.710	40.185	67.550	92.940	273.549	3482.008
102	0.210	0.463	0.658	0.416	11.051	34.803	63.473	92.940	273.549	2262.317
103	0.212	0.463	0.665	0.991	11.404	45.531	71.108	100.779	273.549	4710.567
104	0.211	0.463	0.662	0.659	11.710	40.185	67.550	100.779	273.549	3482.008
105	0.210	0.463	0.658	0.416	11.051	34.803	63.473	100.779	273.549	2262.317
106	0.212	0.463	0.665	0.991	11.404	45.531	71.108	112.694	273.549	4710.567
107	0.211	0.463	0.662	0.659	11.710	40.185	67.550	112.694	273.549	3482.008
108	0.210	0.463	0.658	0.416	11.051	34.803	63.473	112.694	273.549	2262.317
109	0.220	0.479	0.665	0.958	11.024	44.013	68.738	78.493	256.569	4553.559
110	0.219	0.479	0.662	0.637	11.320	38.845	65.299	78.493	256.569	3365.945
111	0.217	0.479	0.658	0.402	10.689	33.643	61.358	78.493	256.569	2186.789
112	0.220	0.479	0.665	0.958	11.024	44.013	68.738	87.171	256.569	4553.559
113	0.219	0.479	0.662	0.637	11.320	38.845	65.299	87.171	256.569	3365.945
114	0.217	0.479	0.658	0.402	10.689	33.643	61.358	87.171	256.569	2186.789
115	0.220	0.479	0.665	0.958	11.024	44.013	68.738	94.524	256.569	4553.559
116	0.219	0.479	0.662	0.637	11.320	38.845	65.299	94.524	256.569	3365.945
117	0.217	0.479	0.658	0.402	10.689	33.643	61.358	94.524	256.569	2186.789
118	0.220	0.479	0.665	0.958	11.024	44.013	68.738	105.699	256.569	4553.559
119	0.219	0.479	0.662	0.637	11.320	38.845	65.299	105.699	256.569	3365.945
120	0.217	0.479	0.658	0.402	10.689	33.643	61.358	105.699	256.569	2186.789
121	0.229	0.499	0.665	0.919	10.583	42.253	65.989	72.467	236.872	4371.426
122	0.228	0.499	0.662	0.612	10.867	37.291	62.687	72.467	236.872	3231.305
123	0.227	0.499	0.658	0.386	10.261	32.298	58.903	72.467	236.872	2099.317
124	0.229	0.499	0.665	0.919	10.583	42.253	65.989	80.479	236.872	4371.426
125	0.228	0.499	0.662	0.612	10.867	37.291	62.687	80.479	236.872	3231.305
126	0.227	0.499	0.658	0.386	10.261	32.298	58.903	80.479	236.872	2099.317
127	0.229	0.499	0.665	0.919	10.583	42.253	65.989	87.267	236.872	4371.426
128	0.228	0.499	0.662	0.612	10.867	37.291	62.687	87.267	236.872	3231.305
129	0.227	0.499	0.658	0.386	10.261	32.298	58.903	87.267	236.872	2099.317
130	0.229	0.499	0.665	0.919	10.583	42.253	65.989	97.585	236.872	4371.426
131	0.228	0.499	0.662	0.612	10.867	37.291	62.687	97.585	236.872	3231.305
132	0.227	0.499	0.658	0.386	10.261	32.298	58.903	97.585	236.872	2099.317
133	0.238	0.519	0.665	0.884	10.176	40.627	63.451	66.905	218.690	4203.278
134	0.237	0.519	0.662	0.588	10.448	35.857	60.276	66.905	218.690	3107.027
135	0.236	0.519	0.658	0.371	9.851	31.055	56.638	66.905	218.690	2018.871
136	0.238	0.519	0.665	0.884	10.176	40.627	63.451	74.302	218.690	4203.278
137	0.237	0.519	0.662	0.588	10.448	35.857	60.276	74.302	218.690	3107.027
138	0.236	0.519	0.658	0.371	9.851	31.055	56.638	74.302	218.690	2018.871
139	0.238	0.519	0.665	0.884	10.176	40.627	63.451	80.569	218.690	4203.278
140	0.237	0.519	0.662	0.588	10.448	35.857	60.276	80.569	218.690	3107.027
141	0.236	0.519	0.658	0.371	9.851	31.055	56.638	80.569	218.690	2018.871
142	0.238	0.519	0.665	0.884	10.176	40.627	63.451	90.094	218.690	4203.278
143	0.237	0.519	0.662	0.588	10.448	35.857	60.276	90.094	218.690	3107.027
144	0.236	0.519	0.658	0.371	9.851	31.055	56.638	90.094	218.690	2018.871
145	0.208	0.463	0.650	2.103	7.319	51.619	83.068	83.688	273.549	6554.754
146	0.208	0.463	0.650	1.383	7.221	46.132	82.144	83.688	273.549	5192.395
147	0.187	0.463	0.587	0.839	11.004	42.241	89.524	83.688	273.549	3978.945
148	0.208	0.463	0.650	2.103	7.319	51.619	83.068	92.940	273.549	6554.754
149	0.208	0.463	0.650	1.383	7.221	46.132	82.144	92.940	273.549	5192.395
150	0.187	0.463	0.587	0.839	11.004	42.241	89.524	92.940	273.549	3978.945
151	0.208	0.463	0.650	2.103	7.319	51.619	83.068	100.779	273.549	6554.754
152	0.208	0.463	0.650	1.383	7.221	46.132	82.144	100.779	273.549	5192.395
153	0.187	0.463	0.587	0.839	11.004	42.241	89.524	100.779	273.549	3978.945
154	0.208	0.463	0.650	2.103	7.319	51.619	83.068	112.694	273.549	6554.754

155	0.208	0.463	0.650	1.383	7.221	46.132	82.144	112.694	273.549	5192.395
156	0.187	0.463	0.587	0.839	11.004	42.241	89.524	112.694	273.549	3978.945
157	0.215	0.479	0.650	2.033	7.075	49.898	80.299	78.493	256.569	6336.254
158	0.215	0.479	0.650	1.337	6.980	44.594	79.406	78.493	256.569	5019.309
159	0.215	0.479	0.650	0.796	6.867	39.279	77.403	78.493	256.569	3712.930
160	0.215	0.479	0.650	2.033	7.075	49.898	80.299	87.171	256.569	6336.254
161	0.215	0.479	0.650	1.337	6.980	44.594	79.406	87.171	256.569	5019.309
162	0.215	0.479	0.650	0.796	6.867	39.279	77.403	87.171	256.569	3712.930
163	0.215	0.479	0.650	2.033	7.075	49.898	80.299	94.524	256.569	6336.254
164	0.215	0.479	0.650	1.337	6.980	44.594	79.406	94.524	256.569	5019.309
165	0.215	0.479	0.650	2.033	7.075	49.898	80.299	105.699	256.569	6336.254
166	0.215	0.479	0.650	1.337	6.980	44.594	79.406	105.699	256.569	5019.309
167	0.215	0.479	0.650	0.796	6.867	39.279	77.403	105.699	256.569	3712.930
168	0.224	0.499	0.650	1.952	6.792	47.903	77.087	72.467	236.872	6082.813
169	0.224	0.499	0.650	1.284	6.701	42.810	76.230	72.467	236.872	4818.535
170	0.224	0.499	0.650	0.764	6.592	37.708	74.307	72.467	236.872	3564.449
171	0.224	0.499	0.650	1.952	6.792	47.903	77.087	80.479	236.872	6082.813
172	0.224	0.499	0.650	1.284	6.701	42.810	76.230	80.479	236.872	4818.535
173	0.224	0.499	0.650	0.764	6.592	37.708	74.307	80.479	236.872	3564.449
174	0.224	0.499	0.650	1.952	6.792	47.903	77.087	87.267	236.872	6082.813
175	0.224	0.499	0.650	1.284	6.701	42.810	76.230	87.267	236.872	4818.535
176	0.224	0.499	0.650	0.764	6.592	37.708	74.307	87.267	236.872	3564.449
177	0.224	0.499	0.650	1.952	6.792	47.903	77.087	97.585	236.872	6082.813
178	0.224	0.499	0.650	1.284	6.701	42.810	76.230	97.585	236.872	4818.535
179	0.224	0.499	0.650	0.764	6.592	37.708	74.307	97.585	236.872	3564.449
180	0.233	0.519	0.650	1.877	6.530	46.060	74.122	66.905	218.690	5848.852
181	0.233	0.519	0.650	1.234	6.443	41.164	73.298	66.905	218.690	4633.207
182	0.233	0.519	0.650	0.735	6.339	36.257	71.449	66.905	218.690	3427.289
183	0.233	0.519	0.650	1.877	6.530	46.060	74.122	74.302	218.690	5848.852
184	0.233	0.519	0.650	1.234	6.443	41.164	73.298	74.302	218.690	4633.207
185	0.233	0.519	0.650	0.735	6.339	36.257	71.449	74.302	218.690	3427.289
186	0.233	0.519	0.650	1.877	6.530	46.060	74.122	80.569	218.690	5848.852
187	0.233	0.519	0.650	1.234	6.443	41.164	73.298	80.569	218.690	4633.207
188	0.233	0.519	0.650	0.735	6.339	36.257	71.449	80.569	218.690	3427.289
189	0.233	0.519	0.650	1.877	6.530	46.060	74.122	90.094	218.690	5848.852
190	0.233	0.519	0.650	1.234	6.443	41.164	73.298	90.094	218.690	4633.207
191	0.233	0.519	0.650	0.735	6.339	36.257	71.449	90.094	218.690	3427.289
192	0.225	0.463	0.704	2.823	7.131	49.968	70.745	83.688	273.549	6141.266
193	0.225	0.463	0.704	1.605	7.039	44.647	69.874	83.688	273.549	4860.129
194	0.225	0.463	0.704	1.022	6.932	39.317	68.830	83.688	273.549	3589.504
195	0.225	0.463	0.704	0.623	6.900	33.970	65.235	83.688	273.549	2306.977
196	0.225	0.463	0.704	2.823	7.131	49.968	70.745	92.940	273.549	6141.266
197	0.225	0.463	0.704	1.605	7.039	44.647	69.874	92.940	273.549	4860.129
198	0.225	0.463	0.704	1.022	6.932	39.317	68.830	92.940	273.549	3589.504
199	0.225	0.463	0.704	0.623	6.900	33.970	65.235	92.940	273.549	2306.977
200	0.225	0.463	0.704	2.823	7.131	49.968	70.745	100.779	273.549	6141.266
201	0.225	0.463	0.704	1.605	7.039	44.647	69.874	100.779	273.549	4860.129
202	0.225	0.463	0.704	1.022	6.932	39.317	68.830	100.779	273.549	3589.504
203	0.225	0.463	0.704	0.623	6.900	33.970	65.235	100.779	273.549	2306.977
204	0.225	0.463	0.704	2.823	7.131	49.968	70.745	112.694	273.549	6141.266
205	0.225	0.463	0.704	1.605	7.039	44.647	69.874	112.694	273.549	4860.129
206	0.225	0.463	0.704	1.022	6.932	39.317	68.830	112.694	273.549	3589.504
207	0.225	0.463	0.704	0.623	6.900	33.970	65.235	112.694	273.549	2306.977
208	0.233	0.479	0.704	2.729	6.893	48.302	68.387	78.493	256.569	5936.543
209	0.233	0.479	0.704	1.551	6.805	43.159	67.545	78.493	256.569	4698.145
210	0.233	0.479	0.704	0.988	6.702	38.006	66.536	78.493	256.569	3469.758

211	0.233	0.479	0.704	0.603	6.671	32.838	63.061	78.493	256.569	2229.985
212	0.233	0.479	0.704	2.729	6.893	48.302	68.387	87.171	256.569	5936.543
213	0.233	0.479	0.704	1.551	6.805	43.159	67.545	87.171	256.569	4698.145
214	0.233	0.479	0.704	0.988	6.702	38.006	66.536	87.171	256.569	3469.758
215	0.233	0.479	0.704	0.603	6.671	32.838	63.061	87.171	256.569	2229.985
216	0.233	0.479	0.704	2.729	6.893	48.302	68.387	94.524	256.569	5936.543
217	0.233	0.479	0.704	1.551	6.805	43.159	67.545	94.524	256.569	4698.145
218	0.233	0.479	0.704	0.988	6.702	38.006	66.536	94.524	256.569	3469.758
219	0.233	0.479	0.704	0.603	6.671	32.838	63.061	94.524	256.569	2229.985
220	0.233	0.479	0.704	2.729	6.893	48.302	68.387	105.699	256.569	5936.543
221	0.233	0.479	0.704	1.551	6.805	43.159	67.545	105.699	256.569	4698.145
222	0.233	0.479	0.704	0.988	6.702	38.006	66.536	105.699	256.569	3469.758
223	0.233	0.479	0.704	0.603	6.671	32.838	63.061	105.699	256.569	2229.985
224	0.242	0.499	0.704	2.619	6.617	46.370	65.651	72.467	236.872	5699.094
225	0.242	0.499	0.704	1.489	6.532	41.433	64.843	72.467	236.872	4510.211
226	0.242	0.499	0.704	0.949	6.434	36.486	63.874	72.467	236.872	3330.945
227	0.242	0.499	0.704	0.579	6.399	31.524	60.538	72.467	236.872	2141.211
228	0.242	0.499	0.704	2.619	6.617	46.370	65.651	80.479	236.872	5699.094
229	0.242	0.499	0.704	1.489	6.532	41.433	64.843	80.479	236.872	4510.211
230	0.242	0.499	0.704	0.949	6.434	36.486	63.874	80.479	236.872	3330.945
231	0.242	0.499	0.704	0.579	6.399	31.524	60.538	80.479	236.872	2141.211
232	0.242	0.499	0.704	2.619	6.617	46.370	65.651	87.267	236.872	5699.094
233	0.242	0.499	0.704	1.489	6.532	41.433	64.843	87.267	236.872	4510.211
234	0.242	0.499	0.704	0.949	6.434	36.486	63.874	87.267	236.872	3330.945
235	0.242	0.499	0.704	0.579	6.399	31.524	60.538	87.267	236.872	2141.211
236	0.242	0.499	0.704	2.619	6.617	46.370	65.651	97.585	236.872	5699.094
237	0.242	0.499	0.704	1.489	6.532	41.433	64.843	97.585	236.872	4510.211
238	0.242	0.499	0.704	0.949	6.434	36.486	63.874	97.585	236.872	3330.945
239	0.242	0.499	0.704	0.579	6.399	31.524	60.538	97.585	236.872	2141.211
240	0.252	0.519	0.704	2.519	6.363	44.587	63.126	66.905	218.690	5479.903
241	0.252	0.519	0.704	1.432	6.281	39.839	62.350	66.905	218.690	4336.735
242	0.252	0.519	0.704	0.912	6.189	35.083	61.418	66.905	218.690	3202.539
243	0.252	0.519	0.704	0.556	6.156	30.312	58.210	66.905	218.690	2058.617
244	0.252	0.519	0.704	2.519	6.363	44.587	63.126	74.302	218.690	5479.903
245	0.252	0.519	0.704	1.432	6.281	39.839	62.350	74.302	218.690	4336.735
246	0.252	0.519	0.704	0.912	6.189	35.083	61.418	74.302	218.690	3202.539
247	0.252	0.519	0.704	0.556	6.156	30.312	58.210	74.302	218.690	2058.617
248	0.252	0.519	0.704	2.519	6.363	44.587	63.126	80.569	218.690	5479.903
249	0.252	0.519	0.704	1.432	6.281	39.839	62.350	80.569	218.690	4336.735
250	0.252	0.519	0.704	0.912	6.189	35.083	61.418	80.569	218.690	3202.539
251	0.252	0.519	0.704	0.556	6.156	30.312	58.210	80.569	218.690	2058.617
252	0.252	0.519	0.704	2.519	6.363	44.587	63.126	90.094	218.690	5479.903
253	0.252	0.519	0.704	1.432	6.281	39.839	62.350	90.094	218.690	4336.735
254	0.252	0.519	0.704	0.912	6.189	35.083	61.418	90.094	218.690	3202.539
255	0.252	0.519	0.704	0.556	6.156	30.312	58.210	90.094	218.690	2058.617
256	0.242	0.463	0.758	2.121	6.786	43.370	59.313	83.688	273.549	4593.906
257	0.242	0.463	0.758	1.181	6.798	38.187	58.325	83.688	273.549	3374.586
258	0.242	0.463	0.758	0.739	6.757	32.986	55.915	83.688	273.549	2162.992
259	0.242	0.463	0.758	2.121	6.786	43.370	59.313	92.940	273.549	4593.906
260	0.242	0.463	0.758	1.181	6.798	38.187	58.325	92.940	273.549	3374.586
261	0.242	0.463	0.758	0.739	6.757	32.986	55.915	92.940	273.549	2162.992
262	0.242	0.463	0.758	2.121	6.786	43.370	59.313	100.779	273.549	4593.906
263	0.242	0.463	0.758	1.181	6.798	38.187	58.325	100.779	273.549	3374.586
264	0.242	0.463	0.758	0.739	6.757	32.986	55.915	100.779	273.549	2162.992
265	0.242	0.463	0.758	2.121	6.786	43.370	59.313	112.694	273.549	4593.906
266	0.242	0.463	0.758	1.181	6.798	38.187	58.325	112.694	273.549	3374.586

267	0.242	0.463	0.758	0.739	6.757	32.986	55.915	112.694	273.549	2162.992
268	0.251	0.479	0.758	2.051	6.560	41.924	57.336	78.493	256.569	4440.824
269	0.251	0.479	0.758	1.141	6.570	36.914	56.381	78.493	256.569	3262.313
270	0.251	0.479	0.758	0.715	6.532	31.887	54.051	78.493	256.569	2090.910
271	0.251	0.479	0.758	2.051	6.560	41.924	57.336	87.171	256.569	4440.824
272	0.251	0.479	0.758	1.141	6.570	36.914	56.381	87.171	256.569	3262.313
273	0.251	0.479	0.758	0.715	6.532	31.887	54.051	87.171	256.569	2090.910
274	0.251	0.479	0.758	2.051	6.560	41.924	57.336	94.524	256.569	4440.824
275	0.251	0.479	0.758	1.141	6.570	36.914	56.381	94.524	256.569	3262.313
276	0.251	0.479	0.758	0.715	6.532	31.887	54.051	94.524	256.569	2090.910
277	0.251	0.479	0.758	2.051	6.560	41.924	57.336	105.699	256.569	4440.824
278	0.251	0.479	0.758	1.141	6.570	36.914	56.381	105.699	256.569	3262.313
279	0.251	0.479	0.758	0.715	6.532	31.887	54.051	105.699	256.569	2090.910
280	0.261	0.499	0.758	1.969	6.297	40.247	55.042	72.467	236.872	4263.231
281	0.261	0.499	0.758	1.096	6.308	35.438	54.126	72.467	236.872	3131.758
282	0.261	0.499	0.758	0.686	6.270	30.611	51.889	72.467	236.872	2007.348
283	0.261	0.499	0.758	1.969	6.297	40.247	55.042	80.479	236.872	4263.231
284	0.261	0.499	0.758	1.096	6.308	35.438	54.126	80.479	236.872	3131.758
285	0.261	0.499	0.758	0.686	6.270	30.611	51.889	80.479	236.872	2007.348
286	0.261	0.499	0.758	1.969	6.297	40.247	55.042	87.267	236.872	4263.231
287	0.261	0.499	0.758	1.096	6.308	35.438	54.126	87.267	236.872	3131.758
288	0.261	0.499	0.758	0.686	6.270	30.611	51.889	87.267	236.872	2007.348
289	0.261	0.499	0.758	1.969	6.297	40.247	55.042	97.585	236.872	4263.231
290	0.261	0.499	0.758	1.096	6.308	35.438	54.126	97.585	236.872	3131.758
291	0.261	0.499	0.758	0.686	6.270	30.611	51.889	97.585	236.872	2007.348
292	0.271	0.519	0.758	1.893	6.055	38.700	52.925	66.905	218.690	4099.203
293	0.271	0.519	0.758	1.054	6.065	34.075	52.044	66.905	218.690	3011.399
294	0.271	0.519	0.758	0.660	6.027	29.434	49.893	66.905	218.690	1930.274
295	0.271	0.519	0.758	1.893	6.055	38.700	52.925	74.302	218.690	4099.203
296	0.271	0.519	0.758	1.054	6.065	34.075	52.044	74.302	218.690	3011.399
297	0.271	0.519	0.758	0.660	6.027	29.434	49.893	74.302	218.690	1930.274
298	0.271	0.519	0.758	1.893	6.055	38.700	52.925	80.569	218.690	4099.203
299	0.271	0.519	0.758	1.054	6.065	34.075	52.044	80.569	218.690	3011.399
300	0.271	0.519	0.758	0.660	6.027	29.434	49.893	80.569	218.690	1930.274
301	0.271	0.519	0.758	1.893	6.055	38.700	52.925	90.094	218.690	4099.203
302	0.271	0.519	0.758	1.054	6.065	34.075	52.044	90.094	218.690	3011.399
303	0.271	0.519	0.758	0.660	6.027	29.434	49.893	90.094	218.690	1930.274
304	0.208	0.463	0.650	2.999	6.781	51.456	85.208	83.688	273.549	6674.336
305	0.208	0.463	0.650	1.970	6.677	45.997	84.264	83.688	273.549	5293.301
306	0.208	0.463	0.650	1.300	6.662	40.526	82.206	83.688	273.549	3907.988
307	0.208	0.463	0.650	0.917	6.485	35.033	78.095	83.688	273.549	2536.270
308	0.208	0.463	0.650	2.999	6.781	51.456	85.208	92.940	273.549	6674.336
309	0.208	0.463	0.650	1.970	6.677	45.997	84.264	92.940	273.549	5293.301
310	0.208	0.463	0.650	1.300	6.662	40.526	82.206	92.940	273.549	3907.988
311	0.208	0.463	0.650	0.917	6.485	35.033	78.095	92.940	273.549	2536.270
312	0.208	0.463	0.650	2.999	6.781	51.456	85.208	100.779	273.549	6674.336
313	0.208	0.463	0.650	1.970	6.677	45.997	84.264	100.779	273.549	5293.301
314	0.208	0.463	0.650	1.300	6.662	40.526	82.206	100.779	273.549	3907.988
315	0.208	0.463	0.650	0.917	6.485	35.033	78.095	100.779	273.549	2536.270
316	0.208	0.463	0.650	2.999	6.781	51.456	85.208	112.694	273.549	6674.336
317	0.208	0.463	0.650	1.970	6.677	45.997	84.264	112.694	273.549	5293.301
318	0.208	0.463	0.650	1.300	6.662	40.526	82.206	112.694	273.549	3907.988
319	0.208	0.463	0.650	0.917	6.485	35.033	78.095	112.694	273.549	2536.270
320	0.215	0.479	0.650	2.899	6.555	49.741	82.368	78.493	256.569	6451.922
321	0.215	0.479	0.650	1.905	6.454	44.463	81.456	78.493	256.569	5116.836
322	0.215	0.479	0.650	1.256	6.440	39.175	79.466	78.493	256.569	3777.582

323	0.215	0.479	0.650	0.887	6.261	33.865	75.492	78.493	256.569	2452.442
324	0.215	0.479	0.650	2.899	6.555	49.741	82.368	87.171	256.569	6451.922
325	0.215	0.479	0.650	1.905	6.454	44.463	81.456	87.171	256.569	5116.836
326	0.215	0.479	0.650	1.256	6.440	39.175	79.466	87.171	256.569	3777.582
327	0.215	0.479	0.650	0.887	6.261	33.865	75.492	87.171	256.569	2452.442
328	0.215	0.479	0.650	2.899	6.555	49.741	82.368	94.524	256.569	6451.922
329	0.215	0.479	0.650	1.905	6.454	44.463	81.456	94.524	256.569	5116.836
330	0.215	0.479	0.650	1.256	6.440	39.175	79.466	94.524	256.569	3777.582
331	0.215	0.479	0.650	0.887	6.261	33.865	75.492	94.524	256.569	2452.442
332	0.215	0.479	0.650	2.899	6.555	49.741	82.368	105.699	256.569	6451.922
333	0.215	0.479	0.650	1.905	6.454	44.463	81.456	105.699	256.569	5116.836
334	0.215	0.479	0.650	1.256	6.440	39.175	79.466	105.699	256.569	3777.582
335	0.215	0.479	0.650	0.887	6.261	33.865	75.492	105.699	256.569	2452.442
336	0.224	0.499	0.650	2.783	6.293	47.751	79.073	72.467	236.872	6193.848
337	0.224	0.499	0.650	1.828	6.196	42.685	78.197	72.467	236.872	4912.164
338	0.224	0.499	0.650	1.207	6.077	37.608	76.287	72.467	236.872	3639.629
339	0.224	0.499	0.650	0.851	6.031	32.511	72.472	72.467	236.872	2352.477
340	0.224	0.499	0.650	2.783	6.293	47.751	79.073	80.479	236.872	6193.848
341	0.224	0.499	0.650	1.828	6.196	42.685	78.197	80.479	236.872	4912.164
342	0.224	0.499	0.650	1.207	6.077	37.608	76.287	80.479	236.872	3639.629
343	0.224	0.499	0.650	0.851	6.031	32.511	72.472	80.479	236.872	2352.477
344	0.224	0.499	0.650	2.783	6.293	47.751	79.073	87.267	236.872	6193.848
345	0.224	0.499	0.650	1.828	6.196	42.685	78.197	87.267	236.872	4912.164
346	0.224	0.499	0.650	1.207	6.077	37.608	76.287	87.267	236.872	3639.629
347	0.224	0.499	0.650	0.851	6.031	32.511	72.472	87.267	236.872	2352.477
348	0.224	0.499	0.650	2.783	6.293	47.751	79.073	97.585	236.872	6193.848
349	0.224	0.499	0.650	1.828	6.196	42.685	78.197	97.585	236.872	4912.164
350	0.224	0.499	0.650	1.207	6.077	37.608	76.287	97.585	236.872	3639.629
351	0.224	0.499	0.650	0.851	6.031	32.511	72.472	97.585	236.872	2352.477
352	0.233	0.519	0.650	2.676	6.051	45.915	76.032	66.905	218.690	5955.621
353	0.233	0.519	0.650	1.758	5.958	41.043	75.190	66.905	218.690	4723.242
354	0.233	0.519	0.650	1.160	5.941	36.161	73.353	66.905	218.690	3487.621
355	0.233	0.519	0.650	0.818	5.790	31.260	69.685	66.905	218.690	2262.781
356	0.233	0.519	0.650	2.676	6.051	45.915	76.032	74.302	218.690	5955.621
357	0.233	0.519	0.650	1.758	5.958	41.043	75.190	74.302	218.690	4723.242
358	0.233	0.519	0.650	1.160	5.941	36.161	73.353	74.302	218.690	3487.621
359	0.233	0.519	0.650	0.818	5.790	31.260	69.685	74.302	218.690	2262.781
360	0.233	0.519	0.650	2.676	6.051	45.915	76.032	80.569	218.690	5955.621
361	0.233	0.519	0.650	1.758	5.958	41.043	75.190	80.569	218.690	4723.242
362	0.233	0.519	0.650	1.160	5.941	36.161	73.353	80.569	218.690	3487.621
363	0.233	0.519	0.650	0.818	5.790	31.260	69.685	80.569	218.690	2262.781
364	0.233	0.519	0.650	2.676	6.051	45.915	76.032	90.094	218.690	5955.621
365	0.233	0.519	0.650	1.758	5.958	41.043	75.190	90.094	218.690	4723.242
366	0.233	0.519	0.650	1.160	5.941	36.161	73.353	90.094	218.690	3487.621
367	0.233	0.519	0.650	0.818	5.790	31.260	69.685	90.094	218.690	2262.781
368	0.225	0.463	0.704	4.284	6.668	49.912	72.498	83.688	273.549	6256.196
369	0.225	0.463	0.704	2.380	6.568	44.606	71.611	83.688	273.549	4955.293
370	0.225	0.463	0.704	1.468	6.442	39.288	70.533	83.688	273.549	3668.524
371	0.225	0.463	0.704	0.975	6.399	33.955	66.921	83.688	273.549	2363.090
372	0.225	0.463	0.704	4.284	6.668	49.912	72.498	92.940	273.549	6256.196
373	0.225	0.463	0.704	2.380	6.568	44.606	71.611	92.940	273.549	4955.293
374	0.225	0.463	0.704	1.468	6.442	39.288	70.533	92.940	273.549	3668.524
375	0.225	0.463	0.704	0.975	6.399	33.955	66.921	92.940	273.549	2363.090
376	0.225	0.463	0.704	4.284	6.668	49.912	72.498	100.779	273.549	6256.196
377	0.225	0.463	0.704	2.380	6.568	44.606	71.611	100.779	273.549	4955.293
378	0.225	0.463	0.704	1.468	6.442	39.288	70.533	100.779	273.549	3668.524

379	0.225	0.463	0.704	0.975	6.399	33.955	66.921	100.779	273.549	2363.090
380	0.225	0.463	0.704	4.284	6.668	49.912	72.498	112.694	273.549	6256.196
381	0.225	0.463	0.704	2.380	6.568	44.606	71.611	112.694	273.549	4955.293
382	0.225	0.463	0.704	1.468	6.442	39.288	70.533	112.694	273.549	3668.524
383	0.225	0.463	0.704	0.975	6.399	33.955	66.921	112.694	273.549	2363.090
384	0.233	0.479	0.704	4.141	6.446	48.249	70.082	78.493	256.569	6047.621
385	0.233	0.479	0.704	2.301	6.349	43.120	69.224	78.493	256.569	4790.125
386	0.233	0.479	0.704	1.419	6.221	37.979	68.181	78.493	256.569	3546.238
387	0.233	0.479	0.704	0.942	6.190	32.823	64.690	78.493	256.569	2283.914
388	0.233	0.479	0.704	4.141	6.446	48.249	70.082	87.171	256.569	6047.621
389	0.233	0.479	0.704	2.301	6.349	43.120	69.224	87.171	256.569	4790.125
390	0.233	0.479	0.704	1.419	6.221	37.979	68.181	87.171	256.569	3546.238
391	0.233	0.479	0.704	0.942	6.190	32.823	64.690	87.171	256.569	2283.914
392	0.233	0.479	0.704	4.141	6.446	48.249	70.082	94.524	256.569	6047.621
393	0.233	0.479	0.704	2.301	6.349	43.120	69.224	94.524	256.569	4790.125
394	0.233	0.479	0.704	1.419	6.221	37.979	68.181	94.524	256.569	3546.238
395	0.233	0.479	0.704	0.942	6.190	32.823	64.690	94.524	256.569	2283.914
396	0.233	0.479	0.704	4.141	6.446	48.249	70.082	105.699	256.569	6047.621
397	0.233	0.479	0.704	2.301	6.349	43.120	69.224	105.699	256.569	4790.125
398	0.233	0.479	0.704	1.419	6.221	37.979	68.181	105.699	256.569	3546.238
399	0.233	0.479	0.704	0.942	6.190	32.823	64.690	105.699	256.569	2283.914
400	0.242	0.499	0.704	3.975	6.188	46.319	67.278	72.467	236.872	5805.680
401	0.242	0.499	0.704	2.209	6.095	41.395	66.455	72.467	236.872	4598.551
402	0.242	0.499	0.704	1.362	5.981	36.460	65.454	72.467	236.872	3404.391
403	0.242	0.499	0.704	0.905	5.926	31.510	62.102	72.467	236.872	2194.110
404	0.242	0.499	0.704	3.975	6.188	46.319	67.278	80.479	236.872	5805.680
405	0.242	0.499	0.704	2.209	6.095	41.395	66.455	80.479	236.872	4598.551
406	0.242	0.499	0.704	1.362	5.981	36.460	65.454	80.479	236.872	3404.391
407	0.242	0.499	0.704	0.905	5.926	31.510	62.102	80.479	236.872	2194.110
408	0.242	0.499	0.704	3.975	6.188	46.319	67.278	87.267	236.872	5805.680
409	0.242	0.499	0.704	2.209	6.095	41.395	66.455	87.267	236.872	4598.551
410	0.242	0.499	0.704	1.362	5.981	36.460	65.454	87.267	236.872	3404.391
411	0.242	0.499	0.704	0.905	5.926	31.510	62.102	87.267	236.872	2194.110
412	0.242	0.499	0.704	3.975	6.188	46.319	67.278	97.585	236.872	5805.680
413	0.242	0.499	0.704	2.209	6.095	41.395	66.455	97.585	236.872	4598.551
414	0.242	0.499	0.704	1.362	5.981	36.460	65.454	97.585	236.872	3404.391
415	0.242	0.499	0.704	0.905	5.926	31.510	62.102	97.585	236.872	2194.110
416	0.252	0.519	0.704	3.822	5.950	44.537	64.691	66.905	218.690	5582.434
417	0.252	0.519	0.704	2.124	5.860	39.803	63.899	66.905	218.690	4421.688
418	0.252	0.519	0.704	1.310	5.740	35.057	62.937	66.905	218.690	3273.453
419	0.252	0.519	0.704	0.870	5.707	30.298	59.714	66.905	218.690	2108.836
420	0.252	0.519	0.704	3.822	5.950	44.537	64.691	74.302	218.690	5582.434
421	0.252	0.519	0.704	2.124	5.860	39.803	63.899	74.302	218.690	4421.688
422	0.252	0.519	0.704	1.310	5.740	35.057	62.937	74.302	218.690	3273.453
423	0.252	0.519	0.704	0.870	5.707	30.298	59.714	74.302	218.690	2108.836
424	0.252	0.519	0.704	3.822	5.950	44.537	64.691	80.569	218.690	5582.434
425	0.252	0.519	0.704	2.124	5.860	39.803	63.899	80.569	218.690	4421.688
426	0.252	0.519	0.704	1.310	5.740	35.057	62.937	80.569	218.690	3273.453
427	0.252	0.519	0.704	0.870	5.707	30.298	59.714	80.569	218.690	2108.836
428	0.252	0.519	0.704	3.822	5.950	44.537	64.691	90.094	218.690	5582.434
429	0.252	0.519	0.704	2.124	5.860	39.803	63.899	90.094	218.690	4421.688
430	0.252	0.519	0.704	1.310	5.740	35.057	62.937	90.094	218.690	3273.453
431	0.252	0.519	0.704	0.870	5.707	30.298	59.714	90.094	218.690	2108.836
432	0.242	0.463	0.758	3.341	6.480	43.408	60.724	83.688	273.549	4668.567
433	0.242	0.463	0.000	0.000	0.000	0.000	59.707	83.688	273.549	0.000

APPENDIX 3

CODE LISTINGS CONFIGURATIONS

GO41C
GO41D
GO41E
GO41F

SYSM MODULE CONFIGURATION GO41C

```
3000 REM SYSM MODULE (27) EXTERNALLY ASSIGN L2 - L7 ,C15H24 FUEL
3010 DATA 3,.5,.56,.7,.5,.8,.25,1.2,3.0,7.5,70,70,375,375,100,1,3731600,.3,15,1.
6
3020 READ FN,FP,VO,UH,UO,EI,EO,BE,PHI,COOL,T(L2),T(L3),TC,T(L6),DE,P,HV,OC,XN,XM

3025 INPUT"ANY UPDATES,YES OR NO";U$:IF U$="YES" THEN STOP
3030 GOSUB 1242:EM=FN/(FN+FP):FG=FN/(EM*EI)
3040 ES=VO/1.2527
3050 A(8,L3)=3413*FN/EO/HV:A(1,L8)=.04112*FG/(VO*UH):HY=A(1,L8)
3055 EF=103872!*UH*A(1,L8)/A(8,L3)/HV
3060 A(2,L3)=PHI*XN*A(8,L3):A(6,L3)=OC*XN*A(8,L3):A(7,L3)=3.733*A(6,L3)
3070 A(6,L4)=A(1,L8)*UH/(2*UO):A(7,L4)=3.7733*A(6,L4)
3080 A(6,L7)=((XN+XN*XM/4)*A(8,L3)-A(6,L4)*UO-A(6,L3))*BE: A(7,L7)=3.733*A(6,L7)

3090 QS=3413*FG*(1-ES)/ES:A(0,L6)=QS/(DE*COOL):A(6,L6)=.21128*A(0,L6):A(7,L6)=(1
-.21128)*A(0,L6):N=L6:T(L6)=TC:P(L6)=P:GOSUB 3410:GOSUB 10
3095 A(2,N3)=XN*XM*A(8,L3)/2:A(5,N3)=XN*A(8,L3):A(6,N3)=(1-UO)*A(6,L4)+(BE-1)*A(
6,L7):A(7,N3)=A(7,L3)+A(7,L7)+A(7,L4)
3100 A(6,L2)=.5*A(2,N3)+A(5,N3)+A(6,N3)+A(6,L9):A(7,L2)=A(7,N3)+A(7,L9)
3110 N=L2:GOSUB 400:GOSUB 3410:GOSUB 10
3120 N=L3:P(N)=1:T(N)=1400:GOSUB 400:GOSUB 3410:LQ=0:GOSUB 10
3130 T(L4)=TC:N=L4:GOSUB 400:GOSUB 3410:GOSUB 10
3140 N=L7:GOSUB 400:GOSUB 10
3147 P(L2)=P:P(L4)=P
3150 RETURN
```

MAIN PROGRAM CONFIGURATION GO41C

```
4160 I9=38:J9=29:K9=39:GOSUB 910
4165 IP=39:OP=40:GOSUB 600:IP=5:OP=6:GOSUB 600
4170 LOCATE 1,1:PRINT"HX2 ANALYSIS";:A5=J5:J5=11:I7=5:J7=6:I8=39:J8=40:N!=1:GOSU
B 1300:IF K(J5)<>0 THEN 4170 ELSE N!(J5)=N!:N!=1 'HX2
4180 IP=40:OP=41:GOSUB 600:IP=13:OP=14:GOSUB 600              'HX4
4185 LOCATE 1,1:PRINT"HX4 ANALYSIS";:A5=J5:J5=6:I7=13:J7=14:I8=40:J8=41:N!=1:GOS
UB 1300:IF K(J5)<>0 THEN 4185 ELSE N!(J5)=N!:N!=1  'HX4
4190 IP=10:OP=58:GOSUB 600:IP=14:OP=15:GOSUB 600
4195 LOCATE 1,1:PRINT"HX3 ANALYSIS";:A5=J5:J5=9:I7=14:J7=15:I8=10:J8=58:N!=1:GOS
UB 1300:IF K(J5)<>0 THEN 4195 ELSE N!(J5)=N!:N!=1 'HX3
4200 STOP:N=35:A(2,N)=A(2,L3):T(N)=140:P(N)=1:GOSUB 400:GOSUB 3410:LQ=1:GOSUB 10
:NV=5:NS!=1:NB!=1
4205 GOSUB 2510:GOSUB 2600
4206 IC=1:A5=12:J5=12:X=NS!:Y=T(M9):YO=T(M1)-15:GOSUB 440:NS!=X:IF K(J5)<>0 THEN
 IB=0:GOTO 4205 ELSE GOSUB 2510
4210 IP=15:OP=16:GOSUB 600:IP=36:OP=37:GOSUB 600
4215 LOCATE 1,1:PRINT"HX5 ANALYSIS";:A5=J5:J5=8:I7=15:J7=16:I8=36:J8=37:N!=1:GOS
UB 1300:IF K(J5)<>0 THEN 4215 ELSE N!(J5)=N!:N!=1
4220 I9=16:J9=18:K9=19:GOSUB 910
4225 N=22:A(6,N)=A(6,29)+A(6,27)+A(6,L4)+A(6,25):A(7,N)=3.773*A(6,N)
4230 T(N)=70:P(N)=1:GOSUB 400:GOSUB 3410:GOSUB 10
4235 QL=0:DT=80:NC!=1:NS!=1:GOSUB 3600
4240 STOP
4250 PRINT "SAVE DATA":STOP:GOSUB 6000:STOP
4260 PRINT "GET DATA":STOP:GOSUB 6040:STOP
```

MAIN PROGRAM CONFIGURATION GO41C (CONTINUED)

```
4000 CLS:LOCATE 12,15:PRINT "MEREDCOM 3 KW POWERPLANT":LOCATE 13,15:PRINT "VERSI
ON 8/24/83"
4010      REM NODE ASSIGNMENTS
4020 L2=20:L3=3:L4=17:L6=26:L7=12:L8=8:L9=24
4030 N1=19:N2=50:N3=33:N4=34:N6=22:N7=51:N8=31    'COND
4040 M1=26:M2=52:M3=53:M4=23:M5=35:M6=54:M7=55:M8=36:M9=56   'BOIL
4075 INPUT"INPUT INITIAL GUESS FOR THE O2  RECYCLE STREAM NODE 24";A(6,L9):A(7,L
9)=3.733*A(6,L9):GOSUB 3000:STOP
4090 GOSUB 3055:IP=3:OP=4:GOSUB 610
4095 IP=4:OP=7:GOSUB 600:N=7:T(N)=400:P(N)=1:GOSUB 10:IP=7:OP=57:GOSUB 1150
4096 IC=1:A5=7:J5=7:N=57:X=A(8,L3):Y=A(1,N):Y0=A(1,L8):EE=.001:GOSUB 440:A(8,L3)
=X:IF K(J5)<>0 THEN 4090:STOP
4100 IP=L4:N=IP:OP=18:DP=0:GOSUB 950
4110 IP=57:OP=L8:GOSUB 600:IP=L8:OP=9:DP=0:GOSUB 990:GOSUB 1200:STOP
4115 N=27:A(6,N)=A(6,L7):A(7,N)=A(7,L7):T(N)=250:P(N)=1:GOSUB 400:GOSUB 3410:GOS
UB 10
4120 I9=9:J9=27:K9=10:GOSUB 910
4125 IP=10:OP=11:GOSUB 600:N=11:T(N)=900:P(N)=1:GOSUB 10
4130 IP=11:OP=12:GOSUB 600:IP=4:OP=5:GOSUB 600
4140 LOCATE 1,1:PRINT"HX1 ANALYSIS";:A5=J5:IC=1:J5=10:I7=4:J7=5:I8=11:J8=12:N!=1
:GOSUB 1300:IF K(J5)<>0 THEN 4140 ELSE N!(J5)=N!:N!=1
4145 IP=12:OP=13:GOSUB 1100                                        'BURN
4150 N=38:A(2,N)=A(2,L3):T(N)=350:P(N)=1:GOSUB 400:GOSUB 3410:GOSUB 10
4155 N=29:A(6,N)=A(6,L3):A(7,N)=A(7,L3):T(N)=250:P(N)=1:GOSUB 400:GOSUB 3410:GOS
UB 10
```

SYSM MODULE CONFIGURATION GO41D

```
3000 REM SYSM MODULE (27) EXTERNALLY ASSIGN L2 - L7 ,CH3OH FUEL
3010 DATA 5,.800,.58,.8,.6,.8,.25,1.2,1.3,000,70,70,375,345,375,35,1,345,1,.41,0
,500,.15,62.4,000,.34,30,2,2,5
3020 READ FN,FP,VO,UH,UO,EI,EO,BE,PHI,COOL,T(L2),T(L3),TC,T(L6),T(L7),DE,P,TB,NB
!,NT!,NJ!,T(IA),EF(7),RO,M,PD,DT,NC!,ND!,A(6,N6)
3025 INPUT"ANY UPDATES,YES OR NO";U$:IF LEFT$(U$,1)="Y" THEN STOP
3027 FOR N=1 TO 25:P(N)=1:NEXT N
3028 GOSUB 1242
3030 EM=FN/(FN+FP):PG=FN/(EM*EI):HR=3957.2/EO
3040 ES=VO/1.2527:EF=1.0726*UH:EO=EF*EM*EI*ES
3050 A(8,L3)=.01174*FN/EO:A(1,L8)=.04112*PG/(VO*UH):H2=A(1,L8)
3052 'CATHODE UTILIZATION IS A FUNCTION OF UH AND BE
3054 UO=UH/(UH+BE*(1-UH))
3060 A(6,L4)=A(1,L8)*UH/(2*UO):A(7,L4)=3.7733*A(6,L4)
3070      'A(6,L7)=BE*(1.5*A(8,L3)-A(6,L4)*UO):A(7,L7)=3.7733*A(6,L7)
3075 A(6,L7)=(1-UO)*A(6,L4):A(7,L7)=A(7,L4)
3080      'A(6,L2)=A(6,L7)+A(6,L4):A(7,L2)=A(7,L7)+A(7,L4)
3081 A(6,L2)=A(6,L4):A(7,L2)=A(7,L4)
3082 A(2,L3)=PHI*A(8,L3):US=1.5*A(8,L3)/A(6,L2)
3084 N=L6:J5=6:A5=J5:A(8,N)=1/(1+PHI):A(2,N)=1-A(8,N)
3086 GOSUB 400:GOSUB 3410:LQ=1:GOSUB 10:IC=1
3088 TB=T(N):NV=3:GOSUB 2420:J5=6:LOCATE 10,10:PRINT"TB VS P(L6)=";P(L6);
3090 X=P(N):Y=TB:YO=345:GOSUB 440:P(N)=X:IF K(J5)<>0 THEN 3088 ELSE IC=0
3092 FOR J=4 TO 7:P(J)=P(N):NEXT J
3094 IP=L6:OP=28:GOSUB 600:N=28:GOSUB 10:LH=(H(28)-H(L6))/2'LATENT HEAT 50%
3100 QS=3413*PG*(1-ES)/ES:A(0,L6)=QS/LH:N=L6:GOSUB 3420:H(L6)=H(6)+LH
3105 FOR J=4 TO 7:IP=L6:OP=J:GOSUB 600:NEXT J
3110 N=L2:GOSUB 400:GOSUB 3410:GOSUB 10
3120 N=L3:GOSUB 400:GOSUB 3410:LQ=1:GOSUB 10
3130 T(L4)=TC:N=L4:GOSUB 400:GOSUB 3410:GOSUB 10
3140 N=L7:GOSUB 400:GOSUB 3410:GOSUB 10
3150 RETURN
```

SYSM MODULE CONFIGURATION GO41D (CONTINUED)

```
3200 REM OUTPUT PRINT SYSTEM DATA BLOCK
3205 LPRINT CHR$(12) TAB(30)CHR$(30)CHR$(15)"SYSTEM DATA BLOCK"CHR$(29)CHR$(14):
LPRINT " "
3210 LPRINT "POWER (KW)":PP=WP+WC+.025: 'CONTROLS P=25 W
3220 LPRINT TAB(10) "NET=";PN,"GROSS=";PG,"PARASITE=";PP
3225 LPRINT TAB(10) "BLWR=";WC,"PUMP=";WP
3230 LPRINT TAB(10)  "CELL VOLTAGE=";VO,"CURRENT DENSITY=";AF;"  ASF"
3235 LPRINT TAB(10)"FUEL CELL AREA=";PG/(VO*AF);" SQFT"
3240 LPRINT "UTILIZATIONS"
3250 LPRINT TAB(10) "HYDROGEN=";UH,"AIR(STACK)=";UO,"AIR(SYSTEM)=";US
3255 BE=(A(6,L7)-A(6,L7+1))/A(6,L7)
3260 LPRINT TAB(10)"BURNER ENRICHMENT=";BE
3270 LPRINT "EFFICIENCY"
3271 ES=VO/1.2527:EM=PN/(PN+PP):EF=.358*A(1,L8)*UH/A(8,L3)
3272 EO=ES*EM*EF*EI:HR=3957.2/EO
3280 LPRINT TAB(10)"OVERALL=";EO,"HEAT RATE=";HR,"BTU/KWH"
3285 ES=VO/1.2527:EF=EO/(EI*ES*EM)
3290 LPRINT TAB(10) "FUEL CELL=";ES,"MECHANICAL=";EM
3300 LPRINT TAB(10)"INVERTER=";EI,"FUEL PROCESSOR=";EF
3310 LPRINT "HX DATA NTU"
3312 LPRINT TAB(10) "CH3OHR=";NT!,"FUEL BOILER=";N6!
3314 LPRINT TAB(10) "HX-7=";N7!,"HX-9=";N9!
3316 LPRINT TAB(10) "COGEN BOILER=";NB!
3318 LPRINT "HX DATA EFFECTIVENESS"
3320 FOR J=1 TO 10:IF EF(J)=0 THEN 3326
3322 LPRINT TAB(10)"EF(";J;")=";EF(J),;
3326 NEXT:LPRINT" "
3330 LPRINT "QBAL DATA"
3332 FOR J=1 TO 40:IF Q(J)=0 THEN 3336
3334 LPRINT TAB(10)"Q(";J;")=";Q(J),;
3336 NEXT:LPRINT" "
3337 LPRINT"COND DATA":LPRINT TAB(10) "NC!=";NC!,"ND!=";ND!:LPRINT TAB(10)"QC=";
QC,"QD=";QD:LPRINT " "
3340 LPRINT "SECANT DATA"
3350 FOR J=1 TO 5:LPRINT "K(";J;")=";SS(J),;:NEXT:LPRINT""
3355 FOR J=6 TO 10:LPRINT "K(";J;")=";SS(J),;
3360 NEXT:LPRINT" ":RETURN
```

MAIN PROGRAM CONFIGURATION GO41D

```
4000    REM configuration g041d.s3e
4005 PRINT"TO ACCESS DATA TYPE GOTO 4220":STOP
4010 'SYSM SETUP  NOTE L2=25 IS DUMMY INLET
4020 L2=25:L3=1:L4=18:L6=5:L7=20:L8=11
4030 GOSUB 3000:CLS:LOCATE 10,10:PRINT"RETURN FROM SYSM"
4035 PRINT"TO ACCESS DATA TYPE GOTO 4220":STOP
4040 'SPLT2 ANALYSIS NOTE ONLY VAPOR AT NODE 9
4050  IP=1:OP=9:GOSUB 600:F=A(8,9)/A(8,5):I9=5:J9=9:K9=6:GOSUB 880
4055 N=9:GOSUB 10:H(6)=H(5)-H(9)
4060 'VALVE 2
4070 IP=9:OP=10:GOSUB 600:P(OP)=1
4080 'CH3OHR/CS
4090 I1=21:I2=22:I3=10:IA=27:I4=27  'NODE 27 IS A DUMMY OF NODE 11
4120 T(IA)=500:GOSUB 2150:N=27:GOSUB 3410'ACCESS COLDSIDE
4130 J5=6:IC=1:A5=J5:X=A(8,1):Y=A(1,27)-A(1,11):Y0=0:GOSUB 440
4132 N=1:A(8,N)=X:A(2,N)=1.3*X:GOSUB 400:GOSUB 3410:GOSUB 10
4134 IF K(J5)<>0 THEN 4050 ELSE IC=0
4138 IP=27:OP=11:T(OP)=375:GOSUB 900
4140 IP=18:OP=19:GOSUB 950'CATHODE
4150 IP=11:OP=12:GOSUB 990'ANODE
4160 GOSUB 1200'PERF
4165 IC=4:AF$="FUEL CELL":AE$="11121819":GOSUB 1980:LOCATE 23,10:PRINT"CURRENT D
ENSITY=";AF;:LOCATE 24,10:PRINT"CELL VOLTS=";V0;
4167 LOCATE 25,1:PRINT"HIT ANY KEY TO CONTINUE"
4169 IF INKEY$="" THEN 4169 ELSE LOCATE 25,1:PRINT"                              "
4170 'MIX3
4180 I9=12:J9=19:K9=20:GOSUB 910
4190 IP=20:OP=21:GOSUB 1100 :TDUM=T(OP)'ACCESS PO
4200 GOTO 4230
```

MAIN PROGRAM CONFIGURATION GO41D (CONTINUED)

```
4210 PRINT"SAVE G041D.DAT":STOP:GOSUB 6000:STOP
4220 PRINT"GET G041D.DAT":STOP:GOSUB 6040:STOP
4225 I1=21:I2=22:I3=10:IA=27:I4=27:TDUM=T(21)   'NODE 27 IS A DUMMY OF NODE 11
4227 CLS:LOCATE 10,15:PRINT"CH3OHR HOTSIDE";
4230 A5=2:IC=1:INPUT"INPUT METHANOL REFORMER HOTSIDE NTU";NT!
4235 GOSUB 2232 'ACCESS CH3OHR HOTSIDE
4236 LOCATE 1,1:PRINT"T(11)=";T(27),"T(21)=";T(21),"T(22)=";T(22)
4237 LOCATE 2,1:PRINT"QHOT=";H(21)-H(22),"QCOLD=";H(27)-H(10),"NT!=";NT!;
4238 KEY OFF:LOCATE 24,1:PRINT "HIT A KEY TO CONTINUE";:IF INKEY$="" THEN 4238
4240 J5=9:A5=J5:X=NT!:Y=H(I1)-H(I2):YO=H(IA)-H(I3):GOSUB 440:GOSUB 5000:NT!=X:IF
 K(J5)<>0 THEN 4235 ELSE
4250 CLS:LOCATE 10,10:PRINT"CONDENSER DESIGN"
4260 N1=22:N2=29:N3=23:N4=24:N6=14:N7=30:N8=15
4262 LOCATE 13,10:INPUT"INPUT CONDENSER AIR INLET TEMP";T(14)
4264 N=14:GOSUB 10:DT=146-T(14)
4270 NC!=1:ND!=5:QL%=0:DT=70
4280 'COLDSIDE SETUP
4290 N=N6:P(N)=1:A(6,N)=5:A(7,N)=3.773*A(6,N)
4300 GOSUB 400:GOSUB 3410:GOSUB 10
4305 IC=4:AF$="COND":AE$="22152314"
4310 GOSUB 3600
4320 GOSUB 3770:GOSUB 3600:GOSUB 1980:LOCATE 1,1:PRINT"NC!=";NC!,"ND=";ND!,"QC="
;QC,"QD=";QD
4330 J5=10:X=DT:Y=A(2,24):YO=A(2,9):EE=.1:GOSUB 440:DT=X
4332 LOCATE 24,1:PRINT "K(J5)=";K(J5);",";"DT=";DT;",";"A(2,9)=";A(2,9);",";"A(2
,24)=";A(2,24);
4334 LOCATE 25,1:PRINT"HIT ANY KEY TO CONTINUE";
4336 IF INKEY$="" THEN 4336 ELSE LOCATE 25,1:PRINT"                         ";
4338 IF K(J5)<>0 THEN 4310
4340 STOP
```

SYSM MODULE CONFIGURATION GO41E

```
3000 REM SYSM MODULE (27) EXTERNALLY ASSIGN L2 - L7 ,CH3OH FUEL
3010 DATA 5,.800,.58,.8,.6,.8,.25,1.2,1.3,000,70,70,375,345,375,35,1,345,1,.41,0
,500,.15,62.4,000,.34,30,2,2,5
3020 READ FN,FP,VO,UH,UO,EI,EO,BE,PHI,COOL,T(L2),T(L3),TC,T(L6),T(L7),DE,P,TB,NB
!,NT!,NJ!,T(IA),EF(7),RO,M,PD,DT,NC!,ND!,A(6,N6)
3025 'INPUT"ANY UPDATES,YES OR NO";U$:IF LEFT$(U$,1)="Y" THEN STOP
3027 FOR N=1 TO 25:P(N)=1:NEXT N
3028 GOSUB 1242
3030 EM=FN/(FN+FP):FG=FN/(EM*EI):HR=3957.2/EO
3040 ES=VO/1.2527:EF=1.0726*UH:EO=EF*EM*EI*ES
3050 A(8,L3)=.01174*FN/EO:A(1,L8)=.04112*FG/(VO*UH):H2=A(1,L8)
3052 'CATHODE UTILIZATION IS A FUNCTION OF UH AND BE
3054 UO=UH/(UH+BE*(1-UH))
3060 A(6,L4)=A(1,L8)*UH/(2*UO):A(7,L4)=3.7733*A(6,L4)
3070      'A(6,L7)=BE*(1.5*A(8,L3)-A(6,L4)*UO):A(7,L7)=3.7733*A(6,L7)
3075 A(6,L7)=(1-UO)*A(6,L4):A(7,L7)=A(7,L4)
3080      'A(6,L2)=A(6,L7)+A(6,L4):A(7,L2)=A(7,L7)+A(7,L4)
3081 A(6,L2)=A(6,L4):A(7,L2)=A(7,L4)
3082 A(2,L3)=PHI*A(8,L3):US=1.5*A(8,L3)/A(6,L2)
3100 QS=3413*FG*(1-ES)/ES
3102 N=L6:T(N)=TC:P(N)=1:A(6,N)=.2095:A(7,N)=1-A(6,N):GOSUB 400:GOSUB 3410:NH=3:
GOSUB 10
3104 A(0,N)=QS/(CP*(T(N)-250)):GOSUB 3420:GOSUB 10
3106 :IP=18:OP=19:GOSUB 600:IP=18:OP=17:GOSUB 600:N=OP:T(N)=250:GOSUB 10
3108 FOR J=6 TO 7:A(J,L2)=A(J,L2)+A(J,L6):NEXT:N=L2:GOSUB 400:GOSUB 3410:GOSUB 1
0
3116 OP=14:IP=L2:OP=N:GOSUB 600
3117 FOR N=21 TO 22:IP=L2:OP=N:GOSUB 600:NEXT N
3120 N=L3:GOSUB 400:GOSUB 3410:LQ=1:GOSUB 10
3130 T(L4)=TC:N=L4:GOSUB 400:GOSUB 3410:GOSUB 10
3140 N=L7:GOSUB 400:GOSUB 3410:GOSUB 10
3150 RETURN
```

SYSM MODULE CONFIGURATION GO41E (CONTINUED)

```
3200 REM OUTPUT PRINT SYSTEM DATA BLOCK
3205 CLS:PRINT "SYSTEM DATA BLOCK":PRINT " "
3210 PRINT "POWER (KW)"
3215 PRINT TAB(10) "NET=";PN,"GROSS=";PG,"PARASITE=";PP
3225 PRINT TAB(10)  "CELL VOLTAGE=";VO,"CURRENT DENSITY=";AF;"  ASF"
3230 ATOT=PG*1000/(VO*AF):AMP=1.4*AF:NC=ATOT/1.4:STACKV=NC*VO
3235 PRINT TAB(10)"FUEL CELL AREA=";ATOT;" SQFT"
3240 PRINT TAB(10)"AMP=";AMP;TAB(20) "STACK VOLTS=";STACKV
3245 PRINT TAB(10)"NUMBER OF CELLS=";NC:PRINT
3250 PRINT "UTILIZATIONS"
3255 PRINT TAB(10) "HYDROGEN=";UH,"AIR(STACK)=";UO
3260 PRINT TAB(10)"BURNER ENRICHMENT=";BE
3265 PRINT "EFFICIENCY"
3270 ES=VO/1.2527:EM=PN/(PN+PP):EF=.358*A(1,L8)*UH/A(8,L3)
3275 EO=ES*EM*EF*EI:HR=3957.2/EO
3280 PRINT TAB(10)"OVERALL=";EO,"HEAT RATE=";HR,"BTU/KWH"
3285 ES=VO/1.2527:EF=EO/(EI*ES*EM)
3290 PRINT TAB(10) "FUEL CELL=";ES,"MECHANICAL=";EM
3295 PRINT TAB(10)"INVERTER=";EI,"FUEL PROCESSOR=";EF
3296 LOCATE 25,1:PRINT"HIT ANY KEY TO CONTINUE";
3297 IF INKEY$="" THEN 3297 ELSE CLS
3300 PRINT "REFORMER DATA"
3301 PRINT TAB(10) "REFORMER NTU=";NT!,"HEAT DUTY=";REFHD;" BTU/HR"
3305 PRINT TAB(10) "REFORMER HEAT TRANSFER AREA=";AREAR;" FT2"
3306 PRINT "BOILER DATA":PRINT TAB(10) 'NTU=";NS!+NB!,"AREA=";ABOIL;" FT2"
3307 PRINT TAB(10)"BOILER HEAT DUTY=";BOILHD;" BTU/HR"
3310 CFM=A(0,22)*6.325:PRINT TAB(10)"FAN CFM=";CFM
3315 GPH=A(0,3)*2.25:PRINT TAB(10)"PUMP GPH=";GPH
3320 PRINT "QBAL DATA"
3325 PRINT TAB(10)"Q(5)=";Q(27)
3330 PRINT"COND DATA":PRINT TAB(10) "NC!=";NC!,"ND!=";ND!:PRINT TAB(10)"QC=";QC;
" BTU/HR","QD=";QD;"BTU/HR"
3332 PRINT TAB(20)"CONDENSER AREA=";ACOND" FT2","HEAT DUTY=";CONDHD;"BTU/HR"
3335 PRINT "SECANT DATA"
3340 FOR J=1 TO 5:PRINT "K(";J;")=";SS(J),;:NEXT:PRINT""
3345 FOR J=6 TO 10:PRINT "K(";J;")=";SS(J),;:NEXT
3346 LOCATE 25,1:PRINT "HIT ANY KEY TO CONTINUE";
3347 IF INKEY$="" THEN 3347 ELSE CLS
3350 PRINT" ":RETURN
```

MAIN PROGRAM CONFIGURATION G041E

```
4000 '=======CONFIGURATION G041E1.S3E MAIN====VERSION 1/9/84========'
4005 'SYSM SETUP  NOTE L2=25 IS DUMMY INLET
4010 L2=13:L3=1:L4=15:L6=18:L7=7:L8=5:KEY OFF
4015 '=====================ACCESS SYSM=====================
4020 GOSUB 3000:CLS:LOCATE 10,10:PRINT"RETURN FROM SYSM"
4025 PRINT"TO ACCESS DATA TYPE GOTO 4230":STOP
4030 '=====================FUEL/WATER MIX ANALYSIS=========
4035 N=L2:GOSUB 1070:CLS
4040 IP=1:OP=10:GOSUB 600:IP=1:OP=3:GOSUB 600:IP=1:OP=2:GOSUB 600:A(2,1)=0:A(8,1
0)=0
4045 N=1:A(2,N)=0:GOSUB 400:GOSUB 3410:LQ=1:GOSUB 10
4050 N=10:GOSUB 400:GOSUB 3410:LQ=1:GOSUB 10
4055 IF A5<>7 THEN IC=5:NXN=120:MYM=160:GOSUB 4440:CLS
4060 '=====================BOILER ANALYSIS=================
4065 M1=18:M2=41:M3=42:M4=19:M5=3:M6=43:M7=44:M8=4:M9=20
4070 NV=3:PW=P(M5)*FR(2,M5):PM=P(M5)*A(8,M5):TB=200:IB=0:NB!=.6:NS!=1.2
4075 IB=0:GOSUB 2510
4080 GOSUB 2600
4085 GOSUB 2510:IC=1:IF A5<>7 THEN A5=6
4090 LOCATE 1,1:PRINT"BOILER NTU ANALYSIS       ":LOCATE 2,1:PRINT"X=NTU SUPRHT"
,"Y=COLDSIDE EXIT TEMP"
4095 J5=6:X=NS!:Y=T(M8):YO=320:GOSUB 440:NS!=X:IF K(J5)<>0 THEN GOSUB 4515:GOTO
4075
4096 BOILS=H(M1)-H(M2):CH=BOILS/(T(M1)-T(M2)):CC=BOILS/(T(M8)-T(M7)):IF CH>CC TH
EN CS=CC ELSE CS=CH
4097 AS=NS!*CS/10
4098 BOILB=H(M2)-H(M4):CH=BOILB/(T(M2)-T(M4)):CC=BOILB/(T(M7)-T(M5)):IF CH>CC TH
EN CS=CC ELSE CS=CH                                               T( 43 )= 176
4099 AB=NB!*CS/100:ABOIL=AS+AB:BOILHD=BOILS+BOILB
4100 IF A5<>7 THEN IC=5:NXN=488:MYM=136:GOSUB 4440
4105 '=====================CH3OHR/COLDSIDE=================
4110 LOCATE 1,1:PRINT"CH3OHR COLDSIDE ANALYSIS":LOCATE 2,1:PRINT"X=FUEL IN, Y=HY
DROGEN TO ANODE        "
4115 I1=8:I2=9:I3=4:IA=27:I4=27  'NODE 27 IS A DUMMY OF NODE 11
4120 T(IA)=500:GOSUB 2150:N=27:GOSUB 3410'ACCESS COLDSIDE
4125 J5=7:IC=1:A5=J5:X=A(8,1):Y=A(1,27)-A(1,5):YO=0:GOSUB 440
4130 N=1:A(8,N)=X:A(2,N)=1.3*X:GOSUB 400:GOSUB 3410:LQ=1:GOSUB 10
4135 IF K(J5)<>0 THEN 4040 ELSE IC=0
4140 IP=27:OP=5:T(OP)=375:GOSUB 900:N=1:A(2,N)=0:GOSUB 400:GOSUB 3410:LQ=1:GOSUB
 10
```

MAIN PROGRAM CONFIGURATION GO41E (CONTINUED)

```
4145 IC=5:NXN=248:MYM=32:GOSUB 4440
4150 '=====================FUEL CELL ANALYSIS==============
4155 IP=15:OP=16:GOSUB 950'CATHODE
4160 IP=5:OP=6:GOSUB 990'ANODE
4165 GOSUB 1200'PERF
4170 IC=4:AF$="FUEL CELL":AE$="5 6 1516":GOSUB 1980:LOCATE 23,10:PRINT"CURRENT D
ENSITY=";AF:LOCATE 24,10:PRINT"CELL VOLTS=";VO
4175 LOCATE 25,1:PRINT "HIT ANY KEY TO CONTINUE";
4180 IF INKEY$="" THEN 4180 ELSE CLS
4185 LOCATE 25,1:FOR J=1 TO 50:PRINT" ";:NEXT:IC=5:NXN=448:MYM=56:GOSUB 4440
4190 '=====================PARTIAL OX/BURN ANALYSIS========
4195 I9=6:J9=16:K9=7:GOSUB 910
4200 IP=7:OP=8:GOSUB 1100 :TDUM=T(OP)'ACCESS PO
4205 NXN=104:MYM=64:GOSUB 4440
4210 'LOCATE 25,1:PRINT"HIT ANY KEY TO CONTINUE";
4215 GOTO 4240 'IF INKEY$="" THEN 4360 ELSE GOTO 4410
4220 '=====================DISCOPS ACCESS==================
4225 PRINT"SAVE G041D.DAT":STOP:GOSUB 6000:STOP
4230 PRINT"GET G041D.DAT":STOP:GOSUB 6040:STOP
4235 I1=8:I2=9:I3=4:IA=27:I4=27  'NODE 27 IS A DUMMY OF NODE 11
4240 CLS:A5=2:IC=1:NT!=1
4245 '=====================CH3OHR HOT SIDE ANALYSIS========
4250 GOSUB 2232 'ACCESS CH3OHR HOTSIDE
4255 LOCATE 1,1:PRINT"T(I1)=";T(I1),"T(I2)=";T(I2),"T(I4)=";T(I4)
4260 LOCATE 2,1:PRINT"QHOT=";H(I1)-H(I2),"QCOLD=";H(I4)-H(I3),"NT!=";NT!;
4265 IC=1 ':LOCATE 24,1:PRINT "HIT A KEY TO CONTINUE";:IF INKEY$="" THEN 4450
4270 J5=9:A5=J5:X=NT!:Y=H(I1)-H(I2):YO=H(IA)-H(I3):GOSUB 440:GOSUB 5000:NT!=X:IF
 K(J5)<>0 THEN  4250
4275 LOCATE 25,1:PRINT "HIT ANY KEY TO CONTINUE";
4280 IF INKEY$="" THEN 4280
4285 IC=5:NXN=272:MYM=56:GOSUB 4440
4286 REFHD=H(I1)-H(I2):CH=REFHD/(T(I1)-T(I2)):CC=REFHD/(T(I3)-T(I4)):IF CH>CC TH
EN CS=CC ELSE CS=CH
4287 AREAR=NT!*CS/10
4290 CLS:LOCATE 10,10:PRINT"CONDENSER DESIGN"
4295 '=====================CONDENSER ANALYSIS==============
4300 N=24:GOSUB 410:F=.4':PRINT"SPLIT F=";F;:INPUT "  INPUT F";F
4305 N=13:FOR J=0 TO 8:A(J,N)=(1-F)*A(J,N):NEXT J:GOSUB 400:GOSUB 10
4310 N1=9:N2=29:N3=11:N4=24:N6=13:N7=30:N8=14'NODE 24 IS DUMMY OF 10
```

MAIN PROGRAM CONFIGURATION GO41E (CONTINUED)

```
4315 NC!=1:ND!=5:QL%=0:DT=70 'INPUT NC!
4320 IF A5<>11 THEN IC=4:AF$="COND":AE$="9 141113":GOSUB 1980
4325 GOSUB 3600
4330 GOSUB 3770:GOSUB 3600:LOCATE 1,1:PRINT"NC!=";NC!,"ND=";ND!,"QC=";QC,"QD=";Q
D:IF A5<>11 THEN GOSUB 1988
4335 LOCATE 2,1:PRINT"TOTAL FLOWS (13)";A(0,13);" (14)";A(0,14);" (22)";A(0,22);
" F=";F
4340 J5=10:X=DT:Y=A(2,N4):Y0=A(2,10):EE=.1:GOSUB 440:DT=X
4345 LOCATE 24,1:PRINT "K(J5)=";K(J5);",";"DT=";DT;",";"A(2,10)=";A(2,10);",";"A
(2,N4)=";A(2,N4);
4350 IF K(J5)<>0 THEN 4325
4355 IF K(11)>3 THEN EE=.01 ELSE EE=.0001
4360 IC=1:J5=11:X=F:Y=T(21):Y0=250:GOSUB 440:F=X:IF K(J5)=0 THEN 4390
4365 IF F<0 THEN F=.0001 ELSE IF F>1 THEN F=.9999
4370 I9=19:J9=23:K9=20:GOSUB 880
4375 N=21:T(N)=T(23)-A(0,14)*(T(23)-T(14))/A(0,21):GOSUB 10:LOCATE 23,1:PRINT "T
(21)=";T(21);
4380 I9=21:J9=23:K9=14:GOSUB 914
4385 T=T(13):IP=14:OP=13:GOSUB 600:N=13:T(N)=T:GOSUB 10:GOTO 4325
4390 IP=21:OP=22:GOSUB 600:IP=24:OP=10:GOSUB 600
4391 CONDD=H(N8)-H(N7):CH=CONDD/(T(N1)-T(N2)):CC=CONDD/(T(N8)-T(N7)):IF CH>CC TH
EN CS=CC ELSE CS=CH
4392 AD=ND!*CS/10
4393 CONDC=H(N7)-H(N6):CH=CONDC/(T(N2)-T(N3)):CC=CONDC/(T(N7)-T(N6)):IF CH>CC TH
EN CS=CC ELSE CS=CH
4394 AC=NC!*CS/100:ACOND=AC+AD:CONDHD=CONDC+CONDD
4395 LOCATE 25,1:PRINT "G041E1.S3E COMPLETE";
4400 IF INKEY$="" THEN 4400
4405 '====================ANALYSIS COMPLETE==============
4410 IC=5:NXN=136:MYM=104:GOSUB 4440
4415 CLS:LOCATE 10,20:PRINT"ANALYSIS COMPLETE, HIT ANY KEY TO CONTINUE"
4420 IF INKEY$="" THEN 4420
4425 GOSUB 3200:GOSUB 4630:GOSUB 1800:GOSUB 6000
4430 IF INKEY$="" THEN 4430 ELSE END
4435 '====================CONFIGURATION SCREEN===========
4440 IF IC<>5 THEN 4505 ELSE CLS:SCREEN 2:KEY OFF:DEF SEG=&HB800:BLOAD"G041E2.PI
C",0:PAINT(NXN,MYM),1
4445 GOSUB 4540
```

```
4450 LOCATE 5,7:PRINT XZ$(7);:LOCATE 6,44:PRINT XZ$(27);:LOCATE 6,63:PRINT XZ$(6
)
4455 LOCATE 10,20:PRINT XZ$(8);:LOCATE 11,9:PRINT XZ$(11);
4460 LOCATE 11,40:PRINT XZ$(9);:LOCATE 11,49:PRINT XZ$(15);
4465 LOCATE 13,70:PRINT XZ$(16);:LOCATE 16,31:PRINT XZ$(23);
4470 LOCATE 15,9:PRINT XZ$(13);:LOCATE 15,24:PRINT XZ$(14);
4475 LOCATE 15,49;PRINT XZ$(17);:LOCATE 16,62:PRINT XZ$(18);
4480 LOCATE 18,16:PRINT XZ$(10);:LOCATE 18,55:PRINT XZ$(19)
4485 LOCATE 19,70:PRINT XZ$(4);:LOCATE 22,9:PRINT XZ$(1);
4490 LOCATE 22,21:PRINT XZ$(2);:LOCATE 21,47:PRINT XZ$(3);
4495 LOCATE 15,41:PRINT XZ$(22);:LOCATE 13,32:PRINT XZ$(21);
4500 LOCATE 18,9:PRINT XZ$(20);
4505 IF Z$<>"R" THEN 4445 ELSE RETURN
4510 '=====================BOILER TEMPERATURE PRINT========
4515 MM(1)=M1:MM(2)=M2:MM(3)=M3:MM(4)=M4:MM(5)=M5:MM(6)=M6:MM(7)=M7:MM(8)=M8:MM(
9)=M9
4520 FOR IZ=1 TO 9:LOCATE IZ,65
4525 PRINT "T(";MM(IZ);")=";USING "####";T(MM(IZ))
4530 NEXT IZ:RETURN
4535 '=====================SCREEN STRING TRANSLATION=======
4540 XZ$="HIT <T> TEMP, <P> PRESSURE, <M> MOLE/HR, <H> ENTHALPY, <R> RETURN"
4545 LOCATE 25,1:PRINT XZ$;
4550 Z$=INKEY$:IF Z$<>"" THEN 4555 ELSE 4550
4555 IF Z$="T" THEN 4560 ELSE IF Z$="P" THEN 4565 ELSE IF Z$="M" THEN 4570 ELSE
IF Z$="H" THEN 4575 ELSE IF Z$="N" THEN 4580 ELSE 4585
4560 FOR J=1 TO 30:XZ$(J)=" "+LEFT$(STR$(T(J)),5):XZ$(J)=RIGHT$(XZ$(J),4):NEXT J
:GOTO 4585
4565 FOR J=1 TO 30:XZ$(J)="   "+LEFT$(STR$(P(J)),4):XZ$(J)=RIGHT$(XZ$(J),4):NEXT
 J:GOTO 4585
4570 FOR J=1 TO 30:XZ$(J)=LEFT$(STR$(A(0,J)),4):NEXT J:GOTO 4585
4575 FOR J=1 TO 30:XZ$(J)=LEFT$(STR$(H(J)/1000),4):NEXT J:GOTO 4585
4580 FOR J=1 TO 30:XZ$(J)="*"+RIGHT$(STR$(J),LEN(STR$(J))-1)+"* ":NEXT J:GOTO 45
85
4585 RETURN
4630 '===============DATA BASE FOR PARAMETRIC ANALYSIS================
4635 ICASE=ICASE+1
```

MAIN PROGRAM CONFIGURATION GO41E (CONTINUED)

```
4640 OPEN "R",1,"SYS1.DAT"
4650 OPEN "R",2,"SYS2.DAT"
4660 OPEN "R",3,"SYS3.DAT"
4670 FIELD 1, 2 AS ICA$,4 AS V1$,4 AS V2$,4 AS V3$,4 AS V4$,4 AS V5$,4 AS V6$,4
AS V7$,4 AS V8$,4 AS V9$,4 AS V10$
4680 FIELD 2,4 AS V11$,4 AS V12$,4 AS V13$,4 AS V14$,4 AS V15$,4 AS V16$,4 AS V1
7$,4 AS V18$,4 AS V19$,4 AS V20$
4690 FIELD 3,4 AS V21$,4 AS V22$,4 AS V23$,4 AS V24$,4 AS V25$,4 AS V26$,4 AS V2
7$,4 AS V28$,4 AS V29$
4695 LSET ICA$=MKI$(ICASE)
4700 LSET V1$=MKS$(PSI):LSET V2$=MKS$(UH):LSET V3$=MKS$(VO):LSET V4$=MKS$(T(L2))
:LSET V5$=MKS$(TATR):LSET V6$=MKS$(PG):LSET V7$=MKS$(PP):LSET V8$=MKS$(AF):LSET
V9$=MKS$(ATOT):LSET V10$=MKS$(NC)
4710 PUT 1,ICASE
4720 LSET V11$=MKS$(VSTACK):LSET V12$=MKS$(AMP):LSET V13$=MKS$(TC):LSET V14$=MKS
$(UO):LSET V15$=MKS$(BE)
4730 LSET V16$=MKS$(PHI):LSET V17$=MKS$(EO):LSET V18$=MKS$(ES):LSET V19$=MKS$(EM
):LSET V20$=MKS$(EI)
4740 PUT 2,ICASE
4750 LSET V21$=MKS$(EF):LSET V22$=MKS$(N!(1)):LSET V23$=MKS$(N!(2)):LSET V24$=MK
S$(Q(5)):LSET V25$=MKS$(CS(1))
4760 LSET V26$=MKS$(CS(2)):LSET V27$=MKS$(AREA(1)):LSET V28$=MKS$(AREA(2))
4770 PUT 3,ICASE
4780 CLOSE:RETURN
```

SYSM MODULE CONFIGURATION GO41F

```
3000 REM SYSM MODULE (27) EXTERNALLY ASSIGN L2 - L7 ,CH3OH FUEL
3010 DATA 5,.800,.58,.6,.6,.8,.25,1.2,1.3,1,4,70,70,375,375,375,35,1,345,1,.41,0
,500,.15,62.4,000,.34,30,2,2,5,.2,1400
3020 READ FN,FP,VO,UH,UO,EI,EO,BE,PHI,XN,XM,T(L2),T(L3),TC,T(L6),T(L7),DE,P,TB,N
B!,NT!,NJ!,T(IA),EF(7),RO,M,PD,DT,NC!,ND!,A(6,N6),PSI,TATR
3021 PRINT"ANY UPDATES,YES OR NO"
3022 U$=INKEY$:IF U$="" THEN 3022 ELSE IF LEFT$(U$,1)="N" OR LEFT$(U$,1) ="n" TH
EN 3038
3024 AA=0:PRINT "INPUT ATR O2/C, DEFAULT =";PSI;:INPUT AA:IF AA<>0 THEN PSI=AA
3025 AA=0:PRINT "INPUT U2 UTILIZATION DEFAULT =";UH;:INPUT AA:IF AA<>0 THEN UH=A
A
3026 AA=0:PRINT "INPUT CELL VOLTS DEFAULT =";VO;:INPUT AA:IF AA<>0 THEN VO=AA
3027 AA=0:PRINT "INPUT AIR INLET TEMP, DEFAULT =";T(L2);:INPUT AA:IF AA<>0 THEN
T(L2)=AA
3028 AA=0:PRINT "INPUT ATR EXIT TEMP, DEFAULT =";TATR;:INPUT AA:IF AA<>0 THEN TA
TR=AA
3038 FOR N=1 TO 25:P(N)=1:NEXT N
3039 GOSUB 1242
3040 EM=FN/(FN+FP):FG=FN/(EM*EI):HR=3957.2/EO
3045 ES=VO/1.2527:EF=1.0726*UH:EO=EF*EM*EI*ES
3050 A(8,L3)=.01174*FN/EO:A(1,L8)=.04112*FG/(VO*UH):REFH2=A(1,L8)
3055 N=L3:GOSUB 400:GOSUB 3410:LQ=1:GOSUB 10 '    DEF L3
3065 A(6,L4)=A(1,L8)*UH/(2*UO):A(7,L4)=3.7733*A(6,L4):N=L4:GOSUB 400:GOSUB 3410:
GOSUB 10  '   DEF L4
3070 A(6,L7)=BE*(1.5*A(8,L3)-A(1,L8)*UH/2-PSI*A(8,L3)):A(7,L7)=3.7733*A(6,L7):N=
L7:GOSUB 400:GOSUB 3410:GOSUB 10'    DEF L7
3085 QS=3413*FG*(1-ES)/ES
3150 RETURN
```

SYSM MODULE CONFIGURATION GO41F (CONTINUED)

```
3200 REM OUTPUT PRINT SYSTEM DATA BLOCK
3205 LPRINT CHR$(27);"@";CHR$(27);"E";TAB(30);CHR$(14);"SYSTEM DATA BLOCK":LPRIN
T CHR$(27);"@"
3210 LPRINT "PARAMETRIC STUDY PARAMETERS":LPRINT"":LPRINT "ATR O2/C= ";PSI
3215 LPRINT "HYDROGEN UTILIZATION ";UH
3220 LPRINT "CELL VOLTS =";VO
3225 LPRINT "AIR INLET TEMP=";T(L2)
3230 LPRINT "ATR EXIT TEMP, DEFAULT =";TATR
3235 LPRINT "POWER (KW)"
3240 LPRINT TAB(10) "NET=";PN,"GROSS=";PG,"PARASITE=";PP
3245 LPRINT TAB(10)  "CELL VOLTAGE=";VO,"CURRENT DENSITY=";AF;"  ASF"
3250 ATOT=PG*1000/(VO*AF):NC=ATOT/1.4:VSTACK=NC*VO:AMP=1.4*AF
3255 LPRINT TAB(10)"FUEL CELL AREA=";ATOT;" SQFT"
3260 LPRINT TAB(10)"NUMBER OF CELLS @ 1.4 FT2=";NC
3265 LPRINT TAB(10)"STACK VOLTS=";VSTACK
3270 LPRINT TAB(10)"STACK CURRENT=";AMP";AMP":LPRINT
3275 LPRINT TAB(10)"CELL TEMPERATURE=";TC;"DEG F"
3280 LPRINT "UTILIZATIONS"
3285 LPRINT TAB(10) "HYDROGEN=";UH,"AIR(STACK)=";UO
3290 LPRINT TAB(10)"BURNER ENRICHMENT=";BE:LPRINT
3295 LPRINT"ATR FUEL PROCESSOR OUTPUT"
3300 LPRINT"WATER TO FUEL RATIO=";PHI,"O2/FUEL RATIO=";PSI
3305 LPRINT "EFFICIENCY"
3310 LPRINT TAB(10)"OVERALL=";EO
3315 LPRINT TAB(10) "FUEL CELL=";ES,"MECHANICAL=";EM
3320 LPRINT TAB(10)"INVERTER=";EI,"FUEL PROCESSOR=";EF:LPRINT
3325 LPRINT "HX DATA NTU"
3326 LPRINT TAB(10) "HX-1=";N!(1),"HX-2=";N!(2)
3327 'ASSUMED U=10
3328 AREA(1)=N!(1)*CS(1)/10:AREA(2)=N!(2)*CS(2)/10
3335 LPRINT "HEAT EXCHANGER AREA"
3336 LPRINT TAB(20)"HX 1 AREA=";AREA(1);" FT2","HX 2 AREA=";AREA(2);" FT2"
3340 LPRINT "QBAL DATA"
3345 FOR J=1 TO 40:IF Q(J)=0 THEN 3355
3350 LPRINT TAB(10)"Q(";J;")=";Q(J),;
3355 NEXT:LPRINT" "
3360 LPRINT "SECANT DATA"
3365 FOR J=1 TO 5:LPRINT "K(";J;")=";SS(J),;:NEXT:LPRINT""
3370 FOR J=6 TO 11:LPRINT "K(";J;")=";SS(J),;
3375 NEXT:LPRINT" ":RETURN
```

MAIN PROGRAM CONFIGURATION GO41F

```
4000 '===================G041F MAIN PROGRAM==========1/27/84=========='
4010 L2=11:L3=1:L4=15:L6=14:L7=21:L8=6
4020 GOSUB 3000 ' CALL SYSM
4025 PRINT"TO ACCESS DISCOPS GET DATA - GOTO 4610":STOP
4030 '===================ASSUME AIR FLOW AT 11========================'
4040 N=11:A(0,N)=30:FR(6,N)=.2095:FR(7,N)=1-FR(6,N):GOSUB 3420
4050 GOSUB 10
4060 '===================EXHAUST NODE 22==============================
4070 N=22:T(N)=TC:A(2,22)=2*A(8,L3)-A(1,L6)*UH:A(5,N)=A(8,L3):A(6,N)=A(6,11)-1.5
*A(8,L3)
4080 A(7,N)=A(7,11):GOSUB 400:GOSUB 3410:GOSUB 10:GOSUB 1070
4090 '===================SPLT3========================================
4100 N=17:A(6,N)=PSI*A(8,L3):T(N)=TC
4110 FOR I=1 TO 8:FR(I,N)=FR(I,22):NEXT I
4120 A(0,N)=A(6,N)/FR(6,N):GOSUB 3420:GOSUB 10:PHI=A(2,N)/A(8,L3):GOSUB 1070
4130 I9=17:J9=22:K9=19:GOSUB 910:GOSUB 1070' DEFINES NODE 19
4140 '===================SPLT2========================================
4150 N=21:T(N)=TC:A(6,N)=BE*(1.5*A(8,L3)-A(1,6)*UH/2-PSI*A(8,L3))
4160 FOR I=1 TO 8:FR(I,N)=FR(I,22):NEXT
4170 A(0,N)=A(6,N)/FR(6,N):GOSUB 3420:GOSUB 10 'DEFINES NODE 21
4180 I9=19:J9=21:K9=18:GOSUB 910' DEFINES NODE 18
4190 '===================SPLT1========================================
4200 N=15:T(N)=TC:A(6,N)=A(1,6)*UH/(2*UO)
4210 FOR I=1 TO 8:FR(I,N)=FR(I,22):NEXT
4230 A(0,N)=A(6,N)/FR(6,N):GOSUB 3420:GOSUB 10 'DEFINES NODE 15
4240 I9=15:J9=18:K9=14:GOSUB 910:GOSUB 1070 'DEFINES NODE 14
4250 '===================FUEL PROCESSOR===============================
4260 I9=17:J9=1:K9=2:GOSUB 920:N=2:GOSUB 1070
4270 IP=2:OP=3:GOSUB 600:EF1=.8:T(3)=T(2)+EF1*(TATR-T(2)):GOSUB 10
4280 IP=3:OP=4:GOSUB 610:IC=1:IF A5< 8 THEN A5=6
4290 J5=6:X=PSI:Y=T(4):YO=TATR:GOSUB 440:IF K(J5)=0 THEN 4410
4300 IF PSI<=0 THEN PSI=.05 ELSE IF PSI>1 THEN PSI=.9 ELSE PSI=X
```

MAIN PROGRAM CONFIGURATION GO41F (CONTINUED)

```
4400 GOTO 4090
4410 IP=4:OP=5:GOSUB 600:H(5)=H(4)-H(3)+H(2):NH=2:N=5:GOSUB 10
4420 IF T(5)>=400 AND T(5)<500 THEN
4430 IP=5:OP=24:GOSUB 600:N=24:T(24)=400:GOSUB 10
4440 T(24)=T(5):Q(5)=H(5)-H(24):T(5)=400:N=5:GOSUB 10
4460 IP=5:OP=6:GOSUB 1150
4470 '===================DEFINE CORRECT HYDROGEN FLOW===============
4480 EF=.35765*A(1,6)*UH/A(8,L3):EO=EF*ES*EI*EM:YO=.04112*PG/(VO*UH):IF A5<=8 TH
EN A5=8
4490 J5=8:X=A(8,L3):Y=A(1,6):GOSUB 440:A(8,L3)=X:N=L3:LQ=1:GOSUB 10:GOSUB 5000:I
F K(J5)<>0 THEN 4060
4500 '===================FUEL CELL=======================================
4510 IP=6:OP=7:GOSUB 990'ANODE
4520 IP=15:OP=16:GOSUB 950 'CATHODE
4530 GOSUB 1200 'PERF
4540 '===================BURNER==========================================
4550 I9=7:J9=21:K9=8:GOSUB 910
4560 IP=8:OP=9:GOSUB 1100
4570 I9=11:J9=9:K9=12:GOSUB 910:IF A5<=9 THEN A5=9
4580 J5=9:X=UH:Y=T(12):YO=250:GOSUB 440:UH=X:GOSUB 5000:IF ER(0,J5)>20  THEN 448
0 ELSE GOSUB 510
4590 J5=10:A5=J5:X=A(0,11):Y=H(14)-H(12):YO=QS:EE=.01:GOSUB 440:A(0,11)=X:GOSUB
5000:IF K(J5)<>0 THEN 4040
4600 STOP:END
4610 '=================DISCOPS ACCESS================================
4620 PRINT"GET DATA":STOP:GOSUB 6040:STOP
4630 PRINT"SAVE DATA":STOP:GOSUB 6000:STOP
```

END

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